REAL-TIME TRANSIT PASSENGER INFORMATION: A CASE STUDY IN STANDARDS DEVELOPMENT

A Thesis
Presented to
The Academic Faculty

by

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In Partial Fulfillment
of the Requirements for the Degree
of Master of Science in the
School of Civil and Environmental Engineering and the
School of City and Regional Planning

Georgia Institute of Technology
December 2013

REAL-TIME TRANSIT PASSENGER INFORMATION: A CASE STUDY IN STANDARDS DEVELOPMENT

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ACKNOWLEDGEMENTS

First and foremost, I wish to thank Rachael Pastor, my fiance and motivational speaker. The weekend coffee shop study sessions certainly helped bring this document line by line to its completion. Your support has been unwavering even though a large section of my brain has been taken over by grad school for the past two and half years. I only hope that I can reciprocate such support when you decide to enter the life of post-graduate projects.

I would also like to thank Kari Watkins, Hans Klein, and Tim Welch, the advisers for this project. Dr. Watkins' support throughout my graduate studies has been phenomenal. Our simultaneous arrival at Georgia Tech was serendipitous and gave the chance to work on instructive and pragmatic projects, from this thesis to the most engaging course projects I have had the opportunity to work on. Discussions with Dr. Klein helped to inspire and refine many of the ideas presented in this research, especially those in which I was the farthest from my comfort zone. The gracious support that Dr. Welch provided as a new member to my thesis committee is much appreciated.

Graduate studies and the production of this thesis were influenced greatly by all of the wonderful colleagues at Georgia Tech, both in SCaRP and Civil Engineering. Thanks to all who contributed to the Urban Transportation Information Lab (UTIL) led by Dr. Watkins, which provided a great environment to learn, share ideas, and gather honest and helpful feedback. Thanks especially to James Wong and Aaron Gooze. These two in particular fulfilled multi-faceted roles in my graduate studies. Friends, colleagues, office mates, intramural teammates, conference co-presenters, and, of course, racquetballers.

This work could not have been completed without the support of the Georgia Department of Transportation or the Georgia Transportation Institute/University Transportation Center at Georgia Tech. Both of these organizations continue to provide support to important and innovative projects in the field of transportation. I would also like to acknowledge the interviewees who generously gave their time and expertise to understanding the standards development processes analyzed in this thesis.

Another thank you to the open transit community for pushing the boundaries in this area. One such member of this community, Dr. Sean Barbeau from the Center for Urban Transportation Research at the University of South Florida, has been a wonderful collaborator on this and other projects during my time here at Georgia Tech. He and other members of this community work to promote open standards in the transit industry by not only implementing and using these standards, but by leading research efforts to better understand this complex ecosystem.

A final thank you goes to my whole family. All of your support and love throughout my life have brought me to this achievement and will continue to push me towards a happy and successful life. My formal (and informal) education was uniquely shaped by each of you.

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LIST OF SYMBOLS AND ABBREVIATIONS

ANSI	American National Standards Institute
APC	Automatic Passenger Counter
APTA	American Public Transit Association
ATIS	Advanced Traveller Information Systems
AVL	Automatic Vehicle Location
CEN	European Committee for Standardization
FCC	Federal Communications Commission
FTA	Federal Transit Administration
GPS	Global Positioning System
GTFS	General Transit Feed Specification
GTFS-realtime	General Transit Feed Specification for Realtime
IETF	Internet Engineering Task Force
ITE	Institute for Transportation Engineers
ITS	Intelligent Transportation Systems
TCIP	Transit Communications Interface Profiles
TCRP	Transit Cooperative Research Program
SDO	Standards Developing Organizations
SSO	Standards Setting Organization
SIRI	Service Interface for Real-time Information
UAV	Unmanned Autonomous Vehicle
V2V	Vehicle-to-vehicle (ITS communications concept)

SUMMARY

As the transportation sector fully integrates information technology, transit agencies face decisions that expose them to new technologies, relationships and risks. Accompanying a rise in transit-related web and mobile applications, a set of competing real-time transit data standards from both public and private organizations have emerged. The purpose of this research is to understand the standard-setting processes for these data standards and the forces that move the transit industry towards the widespread adoption of a data standard. This project will analyze through case studies and interviews with members of standard-setting organizations the development of three real-time transit data standards: (1) the development of the General Transit Feed Specification Realtime (GTFS-realtime), (2) the Service Interface for Real Time Information (SIRI), and (3) Transit Communications Interface Profiles (TCIP). The expected outcome of this research is an assessment of federal policy on standards development as well as an analysis of current and future trends in this sector—both technical and institutional. The results will inform federal transit policy and future action in standards-setting and intelligent transportation systems (ITS) requirements, identifying the potential catalysts that will increase the effectiveness of federal- and agency-level programs.

CHAPTER 1

INTRODUCTION

Passenger information for public transit, particularly in the form of real-time arrival predictions, has experienced a surge of growth in the past decade. While the first passenger information systems existed even in the early 1990s (*1*), the increasing diffusion of mobile smart devices has enabled new generations of applications that allow users to access real-time information with increasing ease and reliability. The benefits of providing this information, especially via mobile applications, are well documented. Such benefits include significant reductions in perceived and actual wait times (*2*), improvements in customer satisfaction (*3*), and increases in transit usage (*4*).

Smartphone market penetration, however, does not fully account for this growth in real-time information delivery. The market success of the standard format for schedule data known as the General Transit Feed Specification (GTFS), originally developed through a partnership between Google and Portland's TriMet, has led to an unprecedented adoption rate by transit agencies as shown by total unlinked passenger trips for agencies with GTFS in Figure 1. These agencies have committed to producing and maintaining their schedule data in standardized CSV tables to display their system on Google Transit's trip planner and, increasingly, opening this data to other third-party application developers.

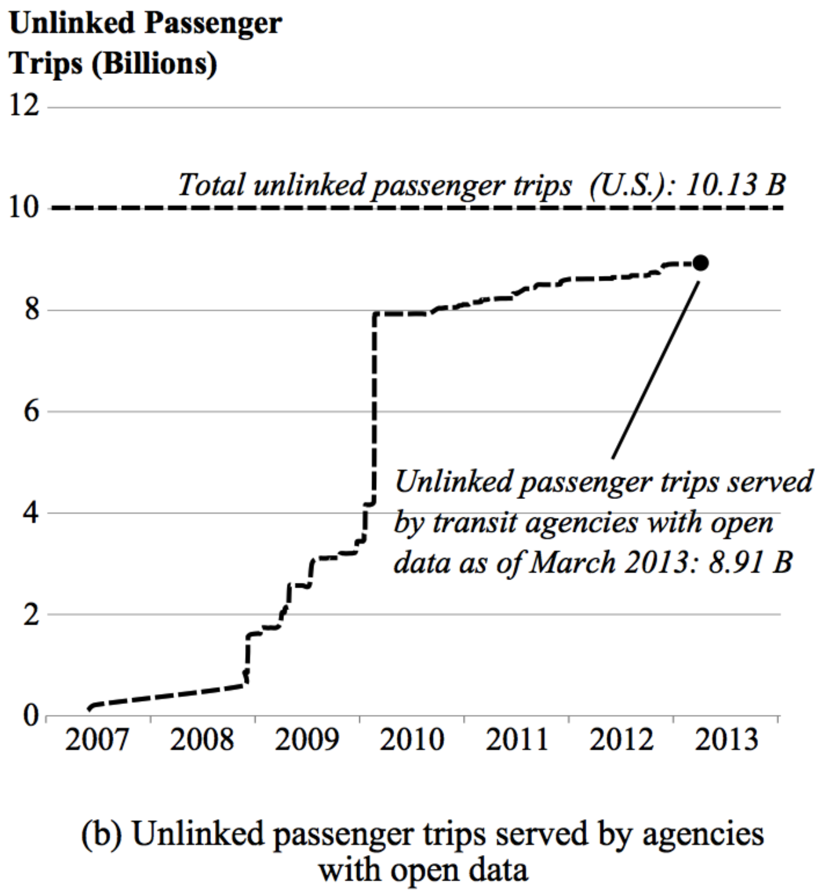

Figure 1 Growth of transit agencies with open data by passenger miles served ***(79)***

While GTFS has emerged as a *de facto* industry standard[1] for static schedule information, there has yet to be a similar case for *real-time* passenger information, or the current location of a transit vehicle and its consequent schedule deviance. Although the menu of real-time data standards is almost identical in composition to the list of options

[1] Some may call attention to the difference between the use of the word "standard" to describe what actually is a specification (for a good description of this difference, albeit in the printing and publishing industry, see http://www.npes.org/pdf/Standards-V-Specs.pdf). While this is a valid semantic concern, the difference between standard and specification lies on a continuum. Specifications that have been widely adopted and are openly maintained begin to move into the realm of standards. For this reason, the words may be interchanged throughout this document. This is not to detract from the respectable and painstaking work of accredited standards bodies, but rather just a side effect of the ever-changing landscape of adoption and usage of standards and specifications.

available for schedule data standards, a predominant alternative has not yet risen to the top. This may be due in part to one or more of the following reasons: (1) the market for real-time information is not mature enough to warrant widespread adoption, (2) the available data standards do not not meet the technical needs of agencies, or (3) the effects of lock-in and switching costs keep agencies fixed in contracts with vendors providing proprietary solutions.

Nonetheless, the market for standards that do exist for real-time transit passenger information in the United States is at a stage where the tipping point for adoption seems likely to occur over the next decade. The open standards for delivering real-time passenger information are (1) the General Transit Feed Specification for realtime (GTFS-realtime), the real-time counterpart of GTFS; (2) Transit Communication Interface Profiles (TCIP), the FTA and APTA's decades-old project that includes specifications for all manner of technology systems in the transit industry; and (3) the Service Interface for Real-time Information (SIRI), a passenger information standard developed by the European Committee for Standardization (CEN), which has seen adoption in whole or part by a few agencies in the US. There are a bevy of other standards for delivering real-time information, but these are on the whole closed standards—generally controlled by proprietary interests without open forums for comments or appeals. Examples of other standards or specifications include the NextBus XML API, web services provided by many different AVL or ITS vendors (Trapeze, Clever Devices, Orbital, etc.), the

OneBusAway API[2], and many custom implementations (such as TriMet's web services API).

There are likely a number of reasons that exist for why a real-time transit passenger information standard has not yet reached a tipping point. This research aims to understand the theory on standards development processes and organizations in an attempt better understand standards development for real-time transit passenger information and why widespread standardization has not occurred. It will examine other cases of competing standards and how these processes were structured. Importantly, it will reflect on standards theory and the role of policy in promoting successful standards.

1.1 Contents

This thesis is presented in six chapters. The present chapter introduces the research goals, structure, and scope. The next chapter gives a background and context for ITS architectures and standards for transportation, more generally, and transit, specifically. It also describes the broader needs for standardization efforts as they pertain to newer government, social, and technological initiatives.

The third chapter thoroughly reviews the theoretical literature that underpins standards development from a variety of academic disciplines including economics, sociology, and political science. This chapter also reviews historical cases of information technology standards development as reference points for the analysis of the real-time

[2] The OneBusAway API is not fully closed, but for the purposes of this research it is not considered here. The primary reason for its exclusion is that most of the discussion and work surrounding the API has been related to a particular implementation of the standard. As the project grows into other regions (New York City, Tampa, Atlanta, etc.) there may be cause to consider it under future research. Another reason for its exclusion here is that the author contributes directly to The OneBusAway Project and wishes to avoid conflicts of interest.

passenger information standards. Finally, the chapter fully introduces the data standards and respective standards development processes under examination in this research.

Chapter four details the case study methodology the author employs for analyzing the passenger information standards development. This chapter documents the case study findings from each of the data collection efforts. These findings and the subsequent analysis inform the concluding chapters in which the author presents recommendations for each of the standards development processes and the larger ITS standardization effort. Research needs and predictions on the future state of the practice are also elaborated on in these final chapters.

1.2 Scope

The literature review and case studies that follow in chapters three and four represent an analysis of standards development with a particular and well-defined scope. The analysis will focus strictly on those standards development processes for real-time passenger information in the United States.

1.2.1 Real-time Passenger Information Transit Data Standards

The scope of this work is limited in order to produce results that are relevant for a particular subset of industry data standards and those organizations that develop those standards. The standards under examination in this research are those that convey passenger information in a real-time context. Such information includes data reported about transit vehicles pertinent to the vehicle locations, schedule adherence/deviance, service disruptions or changes, or even network congestion levels. These data may be used to convey information about transit service that aids travelers in decision making about their journeys.

It is worth noting that certain standards considered here, especially TCIP, contain standards for an entirely other set of information exchanges for the transit industry. GTFS-realtime, on the other hand, was designed and designated strictly for the conveyance of real-time passenger information. As such, a strict "apples to apples" review is not possible unless only the real-time passenger information components of TCIP are considered. While the author recognizes that the real-time component of the standard does not exist in isolation, for the sake of simplicity it will be compared strictly in this real-time passenger information context.

Another important consideration is that TCIP and SIRI were both developed for intra-agency interoperability, whereas GTFS-realtime was developed as a model for external data consumption by third parties. Although on the surface these models exhibit fundamental differences, the primary goal here is to consider how standards influence the ability of transit passengers to consume real-time information. The passenger information components of TCIP, SIRI, and GTFS-realtime all intend to serve this purpose, whether the ultimate vehicle be an agency-operated website or variable message signs, Google Transit, or any number of other web or mobile interfaces. Each of these data standards have the capability to deliver this information; this research will consider how the development of the data standard has hindered or helped to this end.

1.2.2 Process-oriented Analysis

This research effort seeks to understand the evolution, history, and future of the standards development processes of the major real-time passenger information data standards in the United States. By understanding these processes as well as the economic, political, and technical dimensions of these standards, the purpose of this work is to recommend a path forward for the industry in standards adoption and future standards development work, especially as it pertains to real-time passenger information. Rather than a substantive analysis of the content, format, and structure of the data standards, this research effort seeks to understand the formal approaches taken by standards development organizations (SDOs) and the approaches' resultant successes and failures.

1.2.3 United States Focus

While advanced traveller information systems (ATIS) have been deployed for both transit and traffic systems across the world, this research focuses strictly on the United States context. Social and political organization varies country to country as do the makeup of SDOs and their relationship with governmental entities. Because of the complexity of such relationships in different contexts, this research will only consider real-time passenger information standards that have been implemented and used in the United States, particularly for those agencies that are members of the American Public Transit Association (APTA).

SIRI, which was developed through CEN, represents the convergence of a few European real-time information standards, most notably the UK's Real-Time Interest Group (RTIG) and Germany's Verband Deutscher Verkehrsunternehmen (VDV). It also draws on the basic conceptual framework put forth by France's TransModel, also a CEN European Standard. While the SIRI data standard was *developed* through a European SDO with solely European partners, a number of US agencies and real-time information vendors have implemented the standard, bringing it into the pool of other US data standards and into this analysis.

1.2.4 Open Standards

As mentioned above, this research will consider only open standards for real-time transit passenger information. Any recommendations for policy or process are unlikely to impact a closed standard. Therefore, in order to pursue productive work, closed and proprietary specifications are wholly excluded from the case studies and consideration as a possible filler for the real-time transit passenger information standards void. The permanence of proprietary specifications relies on the perpetuity of the firm that holds licensing, intellectual property rights, and general control of the standard. As such, a realistic, long-term solution will not include closed or proprietary specifications. Chapter three considers further the subtleties of open standards and will aid the reader in the understanding of this concept.

CHAPTER 2

BACKGROUND

The purpose and utility of real-time transit information has changed over time. Transit agencies originally installed systems that provided information on vehicle location for operational reasons—to assist with crucial functions such as dispatching. Today, these systems integrate with other technology subsystems such as automatic passenger counters (APCs), influencing the way in which an agency assesses its operations and even communicates with its customers, improving both the quality of service and the customer experience. This section will explore both the technical and historical basis of the technologies that provide this information and how some of these changes have occurred.

2.1 Real-time Transit Information

Real-time transit information provides agencies, operators, and customers with information about the current transit operations—whether it be a single transit vehicle, a route, or an entire fleet.

Automatic vehicle location (AVL) refers to, primarily bus, technology systems that determine the location of a transit vehicle or fleet of vehicles in operation. According to TCRP Synthesis 73, an AVL system is defined as:

> "the central software used by dispatchers for operations management that periodically receives real-time updates on fleet vehicle locations. In most modern AVL systems this involves an onboard computer with an integrated Global Positioning System receiver and mobile data communications capability" (*5*).

One of the primary technologies for early AVL systems installed in the 1970s and 1980s was the wayside signpost beacon system, which relies on a set of signposts installed at key locations on the transit system (sometimes coinciding with features of service like timepoints) and beacons that emit, usually, microwaves to indicate their presence when they approach a signpost. This technology, still used for transit signal priority, is increasingly being replaced by GPS-based systems, wherein each transit vehicle is equipped with a GPS receiver and radio-based mobile communications system.

Transit agencies rely on real-time transit information for a host of operational capabilities and improvements, beyond the information provided specifically for passengers. Updates on the location and status of vehicles can be integrated with a menu of other on- and off-board technology subsystems to provide functionalities such as onboard next stop announcements, automatic data input for headsigns, advanced communication with farebox systems to provide enhanced data on payments, stop-by-stop boardings and alightings, schedule adherence for real-time predictions when linked with schedule data (provided through a number of different interfaces), improved transit signal priority (TSP) operation, and more (*5*). This abbreviated list provides a snapshot of the usefulness of real-time information updates on the location and status of transit vehicles in operation.

Though the menu of options for AVL systems is extensive, the reality of many implementations is that few transit agencies utilize many or all of these capabilities. In a survey conducted by Miller, et al., for TCRP Synthesis 73 (*5*), the researchers asked transit agencies which aspects of the agency's bus AVL system are not fully utilized. The responses for this question are shown in Table 1. While the highest percentage of agencies had not fully utilized TSP (at 43.8%), the second highest response was Next Arrival Predictions at 34.4% of transit agencies (*5*). Over a third of agencies either are not providing or have not fully utilized arrival predictions for their transit systems. The low utilization of TSP can partly be explained by the high capital costs of installing wayside infrastructure and the coordination costs of working with other agencies to calibrate and manage traffic signals. Yet the low utilization of Next Arrival Predictions is not as easily explained by infrastructure costs.

Table 1 Agency responses to question on underutilized AVL functions (*5*)

Technology	%
Transit Signal Priority	43.8
Next Arrival Predictions	34.4
Scheduling and Dispatch Software for Paratransit Operations	31.3
APCs	28.1
Next Stop Announcements	21.9
AVL Software for Fixed-Route Operations	18.8
Other	0.0

While arrival predictions can be delivered with costly wayside digital signage, information delivery via websites, automated telephone systems, or mobile applications offers a low-cost alternative to this infrastructure. One possible explanation for this high response is that when the researchers administered the survey in 2008 these low-cost technologies were less available. This theory can be discredited by survey responses indicating that the earliest cases of agencies delivering next arrival predictions by signs or websites were between 1998-2000 at rates of 9.4% and 3.1%, respectively. Indeed, these low-cost methods were available, but this researcher posits that sufficient dominance of a standard in the realm of real-time transit passenger information had not, and perhaps has still not, matured enough to make these low-cost alternatives to wayside signage economically viable. In the absence of reliable standards, market inefficiencies keep the costs of Next Arrival Predictions too high.

Beyond the underlying technologies and uses, the number of vendors involved in installing and developing these systems for agencies adds an entirely separate layer of complexity. Figure 2 shows the various vendors involved in equipment supply or technology integration mentioned in responses from 31 agencies to a 2008 survey question conducted for TCRP Synthesis 73 (*5*). The wide distribution of responses (note: these responses were not mutually exclusive, i.e., some agencies mentioned multiple vendors/suppliers) suggest that there are a number of both large vendors with multiple contracts across different agencies as well as many cases where smaller vendors may create custom solutions for individual agencies or, at most, small market segments. There are many technology providers for AVL systems and, based on recent evidence, few of these vendors use anything besides proprietary, closed standards for disseminating real-time passenger information within agencies or to third parties.

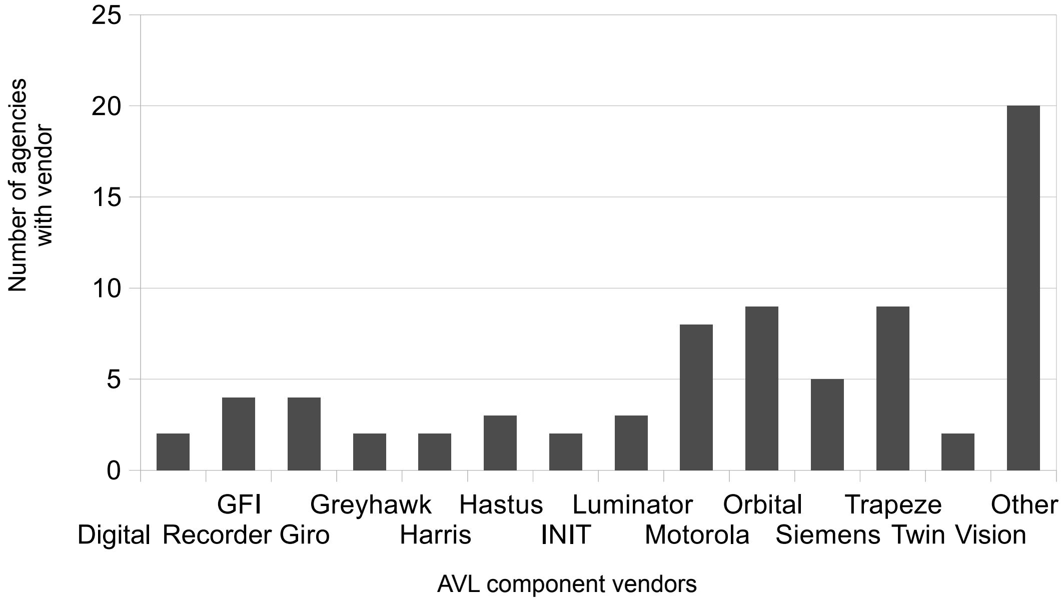

Figure 2 Diversity of technology and equipment vendors for AVL systems (*5*)

2.2 The Need for ITS Data Standards

2.2.1 ITS Architecture / Standards: Final Rule

Intelligent transportation systems (ITS) became a part of the federal agenda in the early 1990s with the passing of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. ITS represent the efforts to integrate information technology into transportation infrastructure at any number of entry points, for example private vehicles or public infrastructure like roadways. Table 2 shows the key activities of the ITS Joint Program Office of the USDOT in 2000 (*6*) and in 2013 (*7*).

Table 2 Comparison of key program interests for ITS in 2000 and 2013 (*6*, *7*)[3]

Date accessed	January 16, 2000	September 3, 2013
Question	*What are the key elements of the ITS metropolitan approach?*	*What are the current key activities of the Federal ITS Program?*
Answer (extract)	Traffic signal control	Vehicle to Vehicle (V2V) Communications for Safety
	Freeway management	Vehicle to Infrastructure (V2I) Communications for Safety
	Transit management	Real-Time Data Capture and Management
	Incident management	Dynamic Mobility Applications
	Electronic toll collection	Road Weather Management
	Electronic fare payment	Applications for the Environment
	Railroad crossings	Human Factors
	Emergency response	Mode-Specific Research
	Regional multi-modal traveler information	Exploratory Research
	--	Cross-Cutting Activities

A comparison of the major activities across the years indicates not necessarily a distinct shift in priorities, but rather a shift in the way the organization addresses these priorities towards more complex and interactive systems. However, the disappearance of any explicit reference to "transit" may indicate a shift in priority to traffic and autos, especially with the ever growing interest in vehicle-to-vehicle (V2V) communications and unmanned autonomous vehicles (UAVs). Nevertheless, this may just as well be explained by the contemporary emphasis on multimodal applications rather than treating modes as discrete, unrelated subjects.

[3] Key program interests for ITS Joint Program Office in 2000 were obtained through the Internet Archive Wayback Machine (https://archive.org/web/). 2013 interests were obtained directly from the ITS Joint Program Office Frequently Asked Questions web page.

In the Transportation Equity Act for the 21st Century, enacted in 1998, legislators filed additional rules for ITS projects that were to be funded by the Highway Trust Fund. These rules specified that any major ITS project must "...conform to the national architecture, applicable standards or provisional standards..." (*8*). This provision extends to any ITS projects funded out of the Mass Transit Account and, therefore, includes most projects that may impact the regional coordination of local ITS operations. It should be clarified that conformance to the "national architecture" in practice requires conformance to a regional ITS architecture, which is based on the National ITS Architecture a much more expansive system than any region is ever likely to implement (*9*).

In response to questions posed during the legislation's comment period, the Federal Transit Administration (FTA) modified the final policy to alleviate concerns regarding "the premature use of required standards and interoperability tests..." Specifically, the FTA relinquished agencies of the need to use any standard that is not yet "mature" and has not been formally adopted by the USDOT. At the time of the modification's writing, the only required standards were those related to commercial vehicle operations (CVO) (*10*). According to a report published in 2010, no other ITS standard has yet to be formally adopted by the USDOT, so it holds that agencies are not formally required to utilize any standard. Nevertheless, the report notes that policy still encourages the use of those standards developed by recognized standards development organizations (SDOs), such as the American Public Transit Association (APTA) (*11*).

Branscomb and Keller (1996) offer an early summary of the challenges facing ITS standardization and, perhaps, partial explanation for why no standard has been formally adopted by the USDOT. In *Converging Infrastructures: Intelligent Transportation and the National Information Infrastructure*, they write:

> "ITS standardization issues are complex relative to those in the traditional telecommunications environment because they span a broader array of technologies and systems. At the same time, however, the environment for standardization is relatively weak. Telecom standards evolved with a common platform and a stable—indeed regulated—competitive environment; ITS will consist of heterogeneous systems and a relatively independent set of players. In addition, many of the technologies for which standards will be most needed are nascent or immature at this time" (*12*).

Many of the same challenges exist nearly two decades later. Technologies and systems remain diverse and complex. Most of the policy efforts tied to standardization have been limited to light incentives, certainly not mandates. And, barring a few examples, standards in the transit industry still seem nascent and/or immature, a fact which is supported by the above mention of USDOT's hesitancy to formally adopt any ITS standard.

Despite this apparent stagnancy, a couple of things have changed dramatically. First, web and mobile platforms for personal information delivery have exploded, despite the survey responses from TCRP Synthesis 73. The personal computer and, more recently, the smartphone have enabled transit agencies—and anyone with an Internet connection—to communicate efficiently with larger and larger audiences. A separate, yet certainly related, occurrence is the emergence of the open data movement. The democratization of information and datasets have created an ever-broadening market of users and implementers who inject a distinct set of values, such as transparency, openness, and sharing, into these standardization processes. In order for standards to succeed in this new marketplace, the bodies that maintain these standards may need to demonstrate a renewed commitment to these ideals—both that the standard is developed/maintained and how new stakeholders might interact with the standard.

2.2.2 Open Data and Standardization

Executive Order (EO) 13642 issued by President Obama on May 9, 2013, has broad-reaching impacts for open data and data standards in the United States (*13*). Proponents of open data, discussed in more depth in Chapter 4, affirm that government should provide its data freely and openly to private citizens and corporations in order to spark innovation and assist government in performing its various functions. Using its oft-cited poster children of weather data and the Global Positioning System (GPS), the EO discusses the immense potential for entrepreneurial activity and economic growth when public data are made freely available. Importantly, it asserts that "the *default state* of new and modernized Government information resources shall be open and machine readable [emphasis added]" (*13*). By providing government data in machine-readable formats by default, the federal government is placing a new level of importance on the role of standardization in the most basic operations of government. Standardization, if not a prerequisite for the systematic provision of machine-readable data, is at the very least a logical conclusion for the effort.

This EO and the policy it represents are important for the future of transit data standards because it cements the pattern of growth and creation of niche data markets in sectors such as transportation, health, or education. With this growth comes the continued importance of data standards to convey this information in addition to the processes by which such standards are developed. While standardization efforts in ITS are over a decade old, the executive branch's relatively new open data policy allows an opportunity to revisit these efforts and investigate how this “open paradigm” might impact preexisting policy and methods. Certainly, most of the ITS standards have been developed to be *open standards*; however, properly functioning in support of open data poses new questions for these transit standards, particularly in how to handle an entirely new set of stakeholders.

2.2.3 Pluralization of Stakeholders

Just as the release of Global Positioning System (GPS) spurred billions of dollars in innovation and supported the spread of businesses around the globe, the opening of historically closed or unavailable datasets is spawning a new set of interests and stakeholders in transportation data from governments. According to a report released in October 2013, open data has the potential to unlock billions, even trillions, of dollars in economic value in the US. For the transportation sector alone there is around $720 to $920 billion in latent value, suggesting that new stakeholders might be very important for the overall economy (*14*). These new interests not only have a stake in if/when an agency releases data, but also in how this data is provided once it is eventually delivered.

This new generation of stakeholders historically has had little influence on the development of ITS standards. This of course is a natural consequence of arriving late to the game, yet this is not to say that such parties have not been addressed. In a 2012 roundtable held by the White House Office of Science and Technology Policy (OSTP), application developers and other transit industry stakeholders met to address challenges facing the transit industry, namely “(1) a lack of consensus on standards for the exchange of real-time transit data and (2) a lack of 'clinical trials' of cutting-edge technologies in this area” (*15*). The direct outcomes of this meeting are not abundantly clear. In fact, that the meeting even took place at all is difficult to ascertain because it is only published on a few blogs. Nonetheless, the convening of such a meeting shows that the federal government is aware of the issues in adoption of current standards and bringing transit technology forward. As more and more agencies move towards an open data model, this pluralization of stakeholders opens up opportunities for transformative change in the public transit industry.

2.2.4 Efficient Competition and Innovation

The most fundamental motivation for pursuing transit ITS or any other set of data standards is to enable efficient competition and innovation. The economic arguments for standardization espouse the positive welfare benefits that widely adopted standards generate and, conversely, the failure of technologies and innovations to which incompatible standards can lead (*16*). Such positive benefits include network effects, the avoidance of lock-in, reduction in switching costs, and enabling new market entrants, all of which will be explored further in later chapters (*17–19*). Put simply, standards lead to a more efficient arrangement of market forces and competition. While the success of standards may not be in the interest of existing firms within the industry, it is certainly in the interest of the general welfare of the public, who perceives such activity in the form of cost reductions and improvements in services.

In considering the value of standards to transit ITS, it is helpful to consider the genesis of GPS technology, Surely if the federal government had delegated the management of GPS to local authorities, we would see the geographies of various jurisdictions encoded differently to serve different needs. A state government may choose to represent each point of latitude and longitude in reference to a coordinate system that distorts the state's geography the least. Or a local municipality may choose to represent every point in reference to the city center, a logical decision. Or an extremely flat county might choose not to represent altitude in its local GPS at all.

In reality, we see different coordinate systems in use in nearly every jurisdiction around the country that hosts geographic data. But if the federal government had disjointed GPS—the foundational technology for pinpointing any user's precise location at any given moment—in this hypothetical way, there would be little chance of the technology having the lasting impact on the world that it has. This illustration is of course flawed (the technology is for *global* positioning, not *local* positioning), yet in an age where technologies can transform the world in mere months given the right conditions and where data have been historically locked down so tightly, the example is not altogether unbelievable.

In sum, the landscape of transit ITS standards may be in a period of change. Thanks to a growing interest in the use of government data by a new set of stakeholders and the formal recognition of these efforts by the President, there is now more than ever a need to understand the impact that standards have on the transit industry. Understanding the economic and policy impacts that standards have is a crucial first step to understanding how individual standards develop and the environments in which they are created.

CHAPTER 3

LITERATURE REVIEW

3.1 Standards Development Theory

Standards development processes, especially in the information technology sector have received a great deal of attention in the past couple of decades. Indeed, it is the success (or failure) of such processes that have led to the fruitful (or in some cases painful) growth of industries that rely on networking and data exchange protocols, i.e., the Internet. Standards development theory draws from the fields of economics, sociology, political science, business and information technology. This interdisciplinary topic area thus has many different contributors bringing a wide range of expertise and background case studies. Nevertheless, a review of such literature reveals common threads and theoretical underpinnings.

In an attempt to cover all relevant aspects of standards development theory for real-time transit passenger information standards, this section will consider:

- the **economic drivers** for standardization processes;
- the **institutions** that have historically steered standardization processes;
- **policymaking** surrounding standardization;
- the **types of standards** and the basic function each serves; and
- the definition of "**open standards**" development (as well as differentiation between "open standards," "open data," and "open source").

This literature review provides a set of objective criteria for understanding and analyzing the real-time transit passenger information standards development. This analysis will inform the economic viability of development strategies, the appropriateness of when and where government has intervened with various policies, and the conditions of openness for each of the standards. Previous work on transit interface standards has not taken this extensive look at the theoretical literature surrounding standards development, yet in order to move the industry forward on this issue, such a review is necessary.

3.1.1 Economic Dimensions of Standards

There are a number of economic motivations for standardization in an industry. Each of these impart externalities onto transactions and product decisions, which spur the economic viability of products and allow technological innovation to proceed at a strong pace.

Network Effects

Some of the primary economic advantages offered by standardization are derived from what are known as network effects. Katz and Shapiro (*20*)define network effects as "the utility that a given user derives from the good [which] depends upon the number of other users who are in the same 'network' as is he or she." Economists have established a number of types of network effects[4] in the past few decades, all of which contribute to an understanding of how these market externalities impact standards development and implementation.

[4]Arun Sundararajan maintains a thorough listing of the various types of network effects on his personal web site (http://oz.stern.nyu.edu/io/network.html) hosted at New York University from which many of the literature references were extracted.

For understanding how network effects might apply to real-time transit passenger information, consider a transit agency in isolation. The agency may have an interest in providing real-time information to customers. Developing a system to deliver this information may take significant investment in labor and/or capital to build the system from scratch. In the absence of standardization, adding additional agencies to this model does not decrease individual agency investments to provide real-time information. However, standardization drives down these costs because the costs (and benefits) of development begin to be distributed across the network. The different ways in which these effects disperse are described below.

Direct Network Effects

The most basic example of network effects and one of the most modeled in the field are direct network effects. Direct network effects account for the direct increase in value accounted for by an increase in usage. Such an effect is easily explained by common communications networks, such as increases in Internet users or the number of households with a telephone. As more individuals begin using a product, the value of that product, or consumption benefit, for existing users and each additional user rises. Both Katz and Shapiro (*20*) and Farrell and Saloner (*19*) discuss these basic effects in their seminal works that were both published in 1985.

Indirect Network Effects

Indirect networks effects contribute to consumption externalities, or the how the consumption of one good may depend on the market supply/availability of other supporting or interoperable goods. Katz and Shapiro also refer to this phenomenon as the hardware-software paradigm (*20*), which may be recognized today in the consumption patterns of smartphones. Indeed, the availability and abundance of “apps” or native applications—or even accessories like cases or peripherals—for a particular consumer smartphone often heavily influences the purchasing decisions of consumers.

The applicability of this indirect network effect model may be limited for the transit ITS industry because of the dominance of vertically integrated vendor solutions for hardware and software. However, the model may be considered for instances where passenger information standards have been adopted by a subset of transit agencies and mobile application developers. In this circumstance, consumers have come to enjoy the benefits of software variety and freedom of choice when a transit agency chooses a standard that allows for an array of software providers to enter the market.

Two-sided Network Effects

Indirect network effects are sometimes referred to as one-directional cases of two-sided network effects. Whereas indirect network effects refer to the scenario where a variety of software packages may influence the consumption of a hardware package, two-sided network effects include this scenario along with the reciprocal, where a variety of hardware options for a given software will impart benefits on the consumption of the software. Farrell and Klemperer list “credit cards, brokers, auctions, matchmakers, conferences, journals, computer platforms, and newspapers” among key examples of two-sided network effects (*21*).

Local Network Effects

Local network effects provide a strong theoretical understanding for standards adoption and development in transit ITS. These effects describe the effects that a small subset of a larger network has on consumption decisions. The federal requirement for developing regional ITS architectures is a policy materialization of these effects. In other words, ITS decisions made by a transit agency in a given metropolitan area will be heavily influenced by the decisions of and existing infrastructure supported by agencies within that same region. Again, this effect is supported by both the theoretical arguments made by Sundararajan (*18*) and the policy mandates from USDOT (*10*).

Lock-in and Switching Costs

Besides the benefits attributed by network effects, the *costs* imparted on consumers where standards do not exist in a market create an important motivation for the introduction of standards. These costs, known as switching costs, may keep a consumer *locked in* to a particular firm (or vendor) because the cost of switching firms is too high or, put differently, "when consumers value forms of *compatibility* that require otherwise separate purchases to be made from the same firm" (*21*).

When considering technology systems in the public transit sector, switching costs may derive from the use of proprietary data formats and standards. Thus, switching from one technology provider to a competitor would require high costs to translate or convert data from one system to the new. Other examples of switching costs and lock-in "include the transaction costs of closing an account with one bank and opening another with a competitor, the learning cost incurred by switching to a new make of computer after having learned to use one make, and the artificial switching costs created by frequent-flyer programs that reward customers for repeated travel on a single airline" (*17*).

Approaches to Standards Coordination

The mechanisms by which a standard develops is an important determinant for coordination, or reaching a harmonic agreement within the industry. Farrell and Saloner

Consider three approaches to coordination for interface or compatibility standards: committee-based, market-based (or "bandwagon"), and hybrid coordination (*22*).

Committee-based Coordination

Committee-based coordination relies on the action of some formal body to achieve standardization across the market participants, while market-based coordination is defined by a set of competitive parties each working independently of one another (*22*). There are many examples of committee coordination in standardization including any standard setting organization that openly allows industry participants to meet and develop a standard through a consensus-based process (e.g., ANSI, ISO, or CEN). The hybrid approach relies on a combination of both market agents working together in a formal committee approach, while simultaneously pursuing a market strategy for a standard.

Farrell and Saloner conclude that, while it may take a significantly longer time, committee-based standard setting will more likely result in interface standards coordination. Though the authors do note that as this process takes longer and longer the marginal benefits ("payoffs") for achieving standardization through committee begin to diminish rapidly (*22*).

Market-based or Bandwagon Coordination

Farrell and Saloner suggest that standardization occurs in the market-based or bandwagon coordination environment when there is a clear leader in the market (a "first mover") that pushes the market into standardization as a side effect of its leadership. They mark key examples of this pattern as when Home Box Office (HBO) adopted VideoCipher, a satellite signal scrambling system that once adopted by the entertainment giant brought widespread coordination across the industry. Another example of this bandwagon approach is with the pre-breakup telecommunications company Bell. When Bell (the firm with the largest market share by far) made decisions on products or standards, smaller companies such as GTE were forced to follow.

The Hybrid Approach

The hybrid approach to standards coordination describes when a firm decides to participate actively in a committee approach while simultaneously pursuing a market-based solution (*22*). This approach could be considered either hedging activity or, more aggressively, covert deception used to make a move on the market with the committee's ignorance. Keil suggests that the hybrid approach—combining market and committee elements into a semi-open alliance of organizations—a model used in the standardization of Bluetooth, is used increasingly by firms to achieve rapid dominance of new technology markets (*23*).

3.1.2 Standards Stakeholder Models

As mentioned in Chapter 2, the role of stakeholders in the development of standards is an important one, especially as this group changes with the government implementation of open data policies. This section contains a few descriptions of stakeholder models, or the types of stakeholders involved with standards development and how their respective interests play out. The section provides a context for the importance of organizations, history, and structures in standards development.

<u>Creators, Users, and Implementers</u>

Krechmer defines a model for stakeholders in open standards development that relies on three categories: creators, implementers, and users (*24*). This is perhaps the most basic hierarchical division of stakeholders, yet it helps to parse out interests in the standardization process. While implementers and creators have the most stake in this process, users have important interests as well that extend beyond the technical components. West (*25*) presents a model with more subtleties, which provides a good description of stakeholders for understanding market forces in this research. Nevertheless, both models presented here prove valuable to understanding the interaction and importance of stakeholder groups.

Creators (Standards Setting Organizations)

Standards setting organizations (SSOs) is a term that has been used to characterize any organization involved in the development of standards, from governmental to non-governmental bodies and from corporations to non-profit foundations. In a 2002 critique on the evolving nature of SSOs, Cargill defines five types of SSOs:

- trade associations,
- Standards Developing Organizations (SDOs),
- consortia,
- alliances, and
- the Open Source software movement (*26*).

Cargill traces the history of SDOs, the definition typically applied for more formally organized SSOs. He uncovers the acceleration of market demand for new technology standards and simultaneous retardation of SDOs' ability to deliver standards in a timely manner. This slowing pace of development originated with the growth of “anticipatory standardization,” whereby shortened product cycles and rapid technology change forced organizations to develop a standard far in advance of when it was needed by the industry (*26*).

This change began to bring about an increasing number of consortia, or alliances of companies with similar objectives, that retracted funding from SDOs, redirecting it towards their own consortia activity. While these consortia on the whole did not participate in anticipatory standardization, the model of standardization began to change towards "existing practice." In this model a company would submit a specification already in practice to be reviewed for standardization by a consortium. The revised and reworked specification would then be submitted to the industry as a standard, though as Cargill accurately notes, "[t]he ultimate authorization, of course, was the take up of the technology by the market (*26*).

The other crucial piece of this creator segment of the standardization hierarchy comes from the influence of the Open Source Software (OSS) movement. This movement, formally initiated in the late 1990s, consists of a large, semi-organized network of individuals and organizations growing increasingly diverse, but with the common goal of creating and improving bodies of universally accessible and redistributable software (*27*).

Members of the OSS community often extend beyond the development of software into the realm of standardization. While it may be on the other end of the continuum from large SDOs, this largely voluntary community has made significant contributions to the development of important open source software projects. The decentralized nature of many of these projects shows important similarities to the successful set of Internet open standards, which are developed in part by the Internet

Engineering Task Force (IETF) (*28*). The model of distributed networks of volunteer technical experts has and will likely continue to have real impacts on how standards are developed. The importance of this model is further discussed in section 3.1.5 Open Standards Development.

Implementers

Implementers are those players in the standardization process that create new products that directly employ the standard under development (*24*). This group, therefore, has a uniquely strong interest in the outcome of a standardization process. However, it is crucial to consider how these interests differ from standards creators (such as an SDO) or the user of one of the implementer's products.

An implementer is concerned not with whether the standard is technically sound, universally accessible, or meets some other idealistic notion of fairness, but rather that the standard is accessible to her and meets the needs of her particular products and market segments (*24*). This description is not to vilify implementers. Some implementers may indeed have goals that the standard conform to firmly held values, but if the standard does not meet an implementer's needs, it is not in her interest to support it. It is useful here to discard the notion that firms in the marketplace enjoy competition—firms would rather the playing game be tilted in their favor, but at the very least will suffer a level playing field.

Users

Users of implementations of a standard have a stake in the standard's success. Truly, when a standard reaches widespread adoption, its users gain benefits from network effects, the freedom from lock-in, and stability in their investment. Krechmer writes that the openness of a standard is increasingly important to end users. This is understandable if we accept that openness implies:

> when multiple implementations of the standard from different sources are available, when the implementation functions in all locations needed, when the implementation is supported over the user-planned service life, and when new implementations desired by the user are backward compatible to previously purchased implementations. (*24*)

The model for open standards has an increasingly visible impact on the standardization process for creators, implementers, and users.

West's Model

West describes a stakeholder model in which there are five distinct groups with interests in open standards development. These classes are: "(1) technology providers, (2) incumbent vendors, (3) vendor challengers, (4) complement providers, and (5) users" (*25*). The model has similarities to Krechmer's simplified model. Technology providers develop the technology on which the standard is based. Oftentimes, this group also accounts for the implementers in Krechmer's model.

Vendors consist of implementers who do not have control of the technology development but do provide products that implement the standard. This group consists of incumbents—those who lead the market and maintain a significant segment thereof—and challengers—market leader competitors who wish to disrupt the control of the market. This challenger group sometimes will create standards alliances or consortia to gain control of the market or, perhaps more accurately, to level the playing field (*25*).

Complement providers are those who provide complementary products for a given standard. These providers' interests are driven primarily by volumes—they desire large market shares for their products with little regard for high profit margins. In other words, they are interested in providing products that piggyback on the successful implementations of a standard. Users, once again, make up the same group of stakeholders as in Krechmer's model. This group ultimately cares about the interoperability of the standard and the resultant benefits derived from achieving interoperability.

We can apply West's stakeholder model to the public transit industry, particularly as it pertains to real-time passenger information. Technology providers are those companies that develop and, more often than not, also implement AVL technology. Many of these same companies compose the group of incumbent vendors. Vendor challengers are more difficult to pin down in this model, but Google and its decision to lead the development of the GTFS-realtime open standard most accurately represents this model. Google has been a disruptive force in the provision of transit data (and a number of other sectors), most notably with the development of GTFS.

There are a number of other vendor challengers engaged in the GTFS-realtime "consortium," but the active members of this group mostly seem to be complement providers. We can think of complement providers in this model as third-party application developers, looking to provide real-time passenger information via apps that piggyback off of information provided via AVL systems. They care not about developing a high-cost, custom solution for a single agency, but rather reaching a large number of users—what we will consider as agencies here.

The question of who the user is somewhat conflated because our public transit agencies are direct users, but ultimately their customers are the beneficiaries. So here we have two sets of users: direct (agencies) and indirect (transit riders). Considering this basic model of stakeholders in the transit industry will be important for understanding stakeholder relations and interests in the case studies in Chapter 4.

3.1.3 Public Policy and Standards Development

Government institutions have substantial influence over standards development not only through the institutions through which they act but also through the public policy they support. Greenstein and Stango note the importance of government decisions in backing standards because of the power to mandate compliance with a given standard. However, the incredible rarity of occasions in which these compliance decisions are reversed is just as important for understanding the role of government in standards development (*29*). The literature provides ample discussion of the benefits and costs of government intervention as well as the conditions under which intervention is most appropriate.

David and Greenstein, drawing on the work of Besen and Johnson on FCC regulatory intervention, indicate the conditions under which different types of intervention may be appropriate. Key among their recommendations are "government should not mandate standards if these are likely soon to require revision… symptoms of ineffective or premature actions should not be ignored—including negative industry reactions and continuing attempts to break from mandated standards… [and] sparse response to a [standardization] proposal may indicate premature action [by the intervening agency]" (*30*, *31*). While the latter two recommendations may be applied retroactively to standardization proposals, the first applies to standardization processes where government has yet to intervene.

While the authors recognize the numerous arguments for intervention to achieve gains in efficiency, David and Greenstein note that there are issues that come with government activity in standards development. These issues nearly all stem from the role that stakeholders are able to play in the process. Typically, vested interests, or incumbent vendors, are the most well represented and gain the most influence in a standards development process. Consequently, old standards will be systematically protected while new stakeholders will likely not be fully represented nor even identified in the process (*30*).

Cabral considers ten different standards battles and the role that government policy has played and can play in favoring or supporting a competing standard. He considers two questions of import for policymakers: *which* standard to support and *when* to intervene. For the first question, Cabral argues that a *patient* policymaker should support the lagging standard, or the one that is likely to prove worthwhile over the long term but has yet to fully mature or see market dominance. The policymaker in a hurry, on the other hand, should back the current leading standard. As to when a policymaker should intervene, the answer is binary again: the patient policymaker should delay any action, the impatient should act now (*32*).

The definition of patience and impatience is, then, at the crux of this theory and how policymakers should react to standards battles. Cabral suggests that this depends on both the policy context, e.g., US vs. Europe vs. Japan, and the industry/technology in question. For example, a government might favor the more centralized, impatient approach of choosing a product early over allowing competitive forces to work through markets (patient). When considering the technology in question, some product cycles are relatively short, which would favor an impatient approach to avoid lagging.

Farrell and Shapiro consider the differences between these policy contexts in the selection of high-definition television (HDTV) standards. Japan and Europe chose a much more centralized approach, demonstrating characteristics of impatience. Each chose a technology-firm combination very early on and supported it through the development of the technology. On the other hand, the United States utilized the resources of competing firms in the HDTV standard selection. Additionally, in the United States terrestrial broadcasting interests carried significant political weight, so displacing these providers by adopting a standard too early was out of the question for the FCC. These differences materialized in a long delay in standard setting and technology development in the United States, yet a side effect of this delay was an improvement in the ultimate technology outcome.

In the United States, the FCC allowed for competitive systems to develop in tandem until it chose a standard from a selection of proposals by 1993 (*33*). At this point, tests were prepared to determine which HDTV proposal was deemed best. The results of the February 1993 tests were, of course, inconclusive. In order to keep development costs down and avoid further competition, companies and organizations involved formed a Grand Alliance to cooperatively set the standard and build a working prototype. Eventually this group submitted a proposal that is very close to what would be approved by the FCC in 1996 (*34*).

This case shows a very patient policymaker in the FCC, which chose to allow competing firms to generate multiple proposals. In turn, this led to these competitors allying themselves in order to reduce duplication of efforts and bring HDTV to the market more rapidly. So, the patient policymaker led to a better standard by creating impatient market actors willing to collaborate. While this is just a single example, it demonstrates some of the reactions policymakers have in different environments and lays a foundation for understanding how policy context and technology influence patience.

<u>De facto vs. de jure</u>

An important distinction in the world of standards development is *de facto* vs. *de jure*, or whether a standard is formally adopted/sponsored or not. The question of "who is the formal adopter/sponsor?" poses difficulties in itself. Yet, typically de facto standards achieve widespread dominance by the action of markets without the formal requirement of a governing body, whereas de jure standards exist under the governance of an accredited SDO.

The examples from FCC above primarily describe activities around quality or safety standards enforced by the regulatory body. However, this regulatory activity is less prevalent for ITS transit interface standards. Technically, there exists no *de* jure standard for transit ITS products because the USDOT has not formally adopted any standard, including the FTA/APTA TCIP. Nevertheless, the USDOT does support standards development activity through accredited standards bodies such as APTA, ITE, and ANSI. Fleming Waguespack (2005) IETF is an example of de facto standards-setting body even though it is challenged by traditional standards and governmental bodies.

> The most popular product will also be the de facto standard, and setting a standard can offer a product a dominant market position. Thus de facto standard setting in these cases is of enormous concern to firms in systems industries and will often be central to their business strategies (*35*).

3.1.4 Technical Dimensions of Standards

Thus far, this review has covered "soft" or social dimensions of data standards. These social components of economic and institutional analysis are critical to a complete understanding of the motivations and interests in standards development. It will be useful, however, to explore the technical dimensions of standards in order to refer to phenomena by their proper names.

In the taxonomy of standards laid out by David, there are three classes of standards: reference standards, which enable the accurate measurement and comparison of different products (i.e., benchmarking); minimum quality or safety standards, such as the expected lifetime or performance of an electronic component; and interface standards, those standards which allow a sprocket developed by Sprockets, Inc. to communicate with a widget manufactured by Widgets Corp. (*36*). Other researchers' taxonomies include additional classes, such as variety reduction standards, which "limit a product to a certain range of characteristics such as size and quality level" (for example, reducing the number of types of screws) (*37*); however, this research will focus on the importance of interface standards to the functioning of passenger information dissemination and the market that supports such activity.

Interface and Compatibility Standards

Interface, or compatibility, standards describe the functional or physical characteristics that are necessary for equipment or systems to exchange information successfully. The standards contained in this research (SIRI, GTFS-realtime, and TCIP) are all interface standards, defining the format, structure, and content of the real-time information exchanged by onboard AVL systems to central servers to third party consumers (either users or application providers). While the exact chain of communication intended for each standard may differ, the basic function of compatibility exists throughout.

Interface standards for IT, while relatively new to the public transit industry, have been considered previously in academic literature. In 1998, Hickman reviewed the current state of the practice for interface standards. His review included a survey of 300 software and hardware product vendors in the transit industry. The resultant response rate of about 9% (only 27 fully usable responses) perhaps indicates a lack of interest in the topic matter, a lack of knowledge, or a desire to remain silent on the subject. Whether this response rate is indicative of a particular stance on the topic or simply the consequence of happenstance, Hickman does note that his sample may be seriously biased and should be "viewed with healthy skepticism" (*38*).

3.1.5 Open Standards Development

Standards development takes place in a variety of settings under different institutional arrangements and technical requirements. However, all of the standards considered in this paper have one thing in common: they all claim to be open standards. An open standard is simply a standard that is "not under the control of a single vendor and is easily available to those who need it to make products or services" (*39*). This is a rudimentary definition because there are many facets of openness, which will be considered below. This section will also explore related "open" movements and the interaction between these trends and open standards development.

Components of Open Standards

There are, of course, a wide array of definitions for what makes an open standard. Krechmer documents a few of these, which range from West's availability beyond the standard sponsor to Perens' definition which draws from the open source software movement. Perens emphasizes not just the development and availability of a standard, but also the accepted practices and operating for a standard. His fundamental list of principles and practices include:

1. availability,
2. maximize end-user choice,
3. no royalty,
4. no discrimination,
5. extension or subset, and
6. predatory practices (*40*).

Krechmer recognizes the importance of different stakeholder groups to open standards: if a standard is only open for users and not creators, it is not truly open. For creators, the development process must allow for open meetings, certain consensus criteria, and formal procedures, such as balloting. Implementers have market needs upon which an open standard must not impinge—namely, that the standard should not impose burdensome costs, keep them from innovation, or put them otherwise in a negative market position. Similarly, users consider a standard open when there are multiple implementations to access—such as the availability of GTFS from multiple transit agencies—and there is sufficient support for the standard. Krechmer's ultimate definition, therefore, defines ten requirements that draw upon the expectations of openness from each of these stakeholder groups:

1. **Open meeting** – requires that all stakeholders can participate in meetings; different levels of barriers (economic, physical distance) can detract from an SDO meeting this requirement.
2. **Consensus** – decisions on standard should be made by consensus, a term that has a range of meanings; however, Krechmer views compliance with this requirement to be binary.
3. **Due process** – requires that "consideration be given to the views and objections of all participants" and that processes exist for participants to express such perspectives.
4. **Open world –** suggests that any standard shall, in principle, be applicable to use cases around the world. In other words, it should not be restricted by national or political boundaries. However, because there are often regional or cultural issues involved with standards, the requirement focuses on the geographic coverage in which the standard operates.
5. **Open Intellectual Property Rights (IPR)** – refers to the license that governs the use, redistribution, or commercialization of a standard for implementations. Krechmer scales this requirement in five levels from 0 to 4 ranging from 0 – commercial licensing to 4 – no copyright/patent protection.

6. **Open change –** is a somewhat redundant requirement in which Krechmer bundles the first three requirements (open meeting, consensus, and due process). Nevertheless, the requirement does indicate an important characteristic that relies on the convergence of key principles and so may justify being addressed separately.
7. **Open documents** – requires that documents for the standard development process are made open. This includes "work-in-progress documents" (e.g., draft versions of a standard, meeting discussions, technical reports, etc.) and "completed standard documents." Krechmer describes three states of open documents:
    1. Work-in-progress documents are only available to committee members (standards creators). Standards are for sale. (Current state of most formal SSOs.)
    2. Work-in-progress documents are only available to committee members (standards creators). Standards are available for little or no cost. (Current state of many consortia.)
    3. Work-in-progress documents and standards are available for reasonable or no cost. (Current state of IETF.) (*24*)
8. **Open interface –** prescribes that standards support both backward and forward compatibility. This category could be broken down into *connectivity*, or how devices in different spatial locations interact; *extensibility*, allowing modifications to standards that do not break compatibility; and *adaptability*, allowing for changes in communication system.

9. **Open access** – is a somewhat nebulous requirement that Krechmer seems to attach more to safety standards than interface standards. Nevertheless, it could be interpreted to indicate the degree of access users have to implementations of the standard or the availability of conformance verification tools to verify compliance.
10. **On-going support –** requires that a standard be supported during the four phases of its lifetime (following creation): fixes, maintenance, availability, and rescission.

According to Krechmer, these requirements fully satisfy the Perens definition of open standards, including both principles—One World holds that a single standard ought to perform a capability globally, for all cases—and practices—Open Meeting requires that any and all may play an active role in standards development. Table 3 shows how the ten requirements of Krechmer's definition apply to the three stakeholder groups. The table indicates that three requirements—One World, Open IPR, and Open Change—impact all three stakeholder groups. Users and implementers rely on nearly all of the same requirements, except that implementers do not rely on on-going support.

Table 3 Importance of open standards requirements to different stakeholders (*24*)

Requirements		*Stakeholders*		
		Creator	*Implementer*	*User*
1	Open Meeting	X		
2	Consensus	X		
3	Due Process	X		
4	One World	X	X	X
5	Open IPR	X	X	X
6	Open Change	X	X	X
7	Open Documents		X	X
8	Open Interface		X	X
9	Open Access		X	X
10	On-going Support			X

In addition to a robust definition of open standards, Krechmer provides an analytical framework for assessing open standards development. Because the author uses this framework for assessing passenger information standards in the chapter on case studies, Krechmer's ten requirements, and their relevance for transit ITS standards, will be further explored in Chapter 4.

Related "Open" Movements

In recent years, a number of technology-centric movements labeled with the "open" qualifier have emerged. The author has cursorily reviewed open data with respect to the White House's policy stance and its potential impact on standards development. This brief section is to clarify this and other movements and their relevance for this research.

Open Data

Perhaps the most recent open movement and the one most successful at capturing the public eye has been the "open data" movement. Open data refers to the idea that datasets, particularly those owned by the government, should be made openly available to any private citizen or company that wishes to use them. In addition, the movement holds that governmental agencies should provide such data in machine-readable, common data formats so that they may be easily parsed by software developers, researchers, and any other interested party. Open data holds a strong connection to the world of open standards because the success of the movement relies on being able to build robust, repeatable applications that function for both Agency X and Agency Y. In other worlds, interface standards must be used by a large group of agencies in order for users to experience the benefit of network effects.

Open Source

The open source software movement is a relatively new concept, but has already had profound impacts on the software development industry. Open source refers to a software development model that promotes free redistribution of software and software components, makes source code (not just compiled code) openly available, and allows derivative works (*41*). There are a variety of licenses under which open source software is published (*42*), ranging from the very permissive (for example reuse for commercial purposes) to more restrictive policies on how source code may be used.

The roots of the term "open source" grow very much out of the world of standards. The term was coined in a Palo Alto, California, strategy session following the decision to publicly release the Netscape Navigator source code (*27*). Netscape was embroiled in longstanding "browser wars" with Internet Explorer. which it eventually lost. The ultimate conclusion of these wars, however, would spark the open source movement and the eventual destruction of IE's hegemony by open source browser projects such as Mozilla Firefox and Chromium (the open source basis for Google Chrome).

This movement has since grown astronomically, especially over the past decade. Figure 3 Shows the exponential growth in the number of source lines of code contributed to open source repositories tracked by Deshpande and Riehle over the period of January 1995 to December 2006. While this study is a few years old, the trend line is unmistakable: the open source community is growing rapidly. According to the authors, "the total amount of source code and the total number of projects double about every 14 months" (*43*).

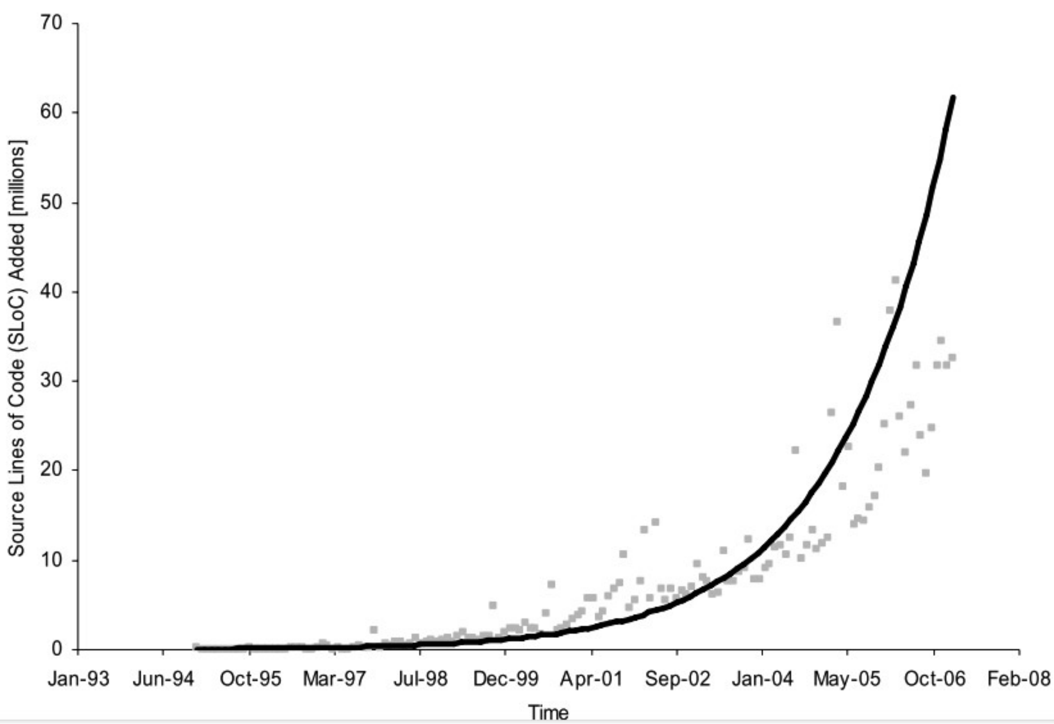

Figure 3, Growth of open source lines of code from 1995 to 2006 (*43*)

While the open movements discussed here have distinct meanings, they do not exist in isolation. It is likely that as open data and open standards proliferate, so too will the number of open source projects and lines of code dedicated to using these data and standards. This correlation is not a given, yet the interest in civic hacking (*44*) and viewing government as a platform (*28*) suggest that these movements will work together in concert and continue to exhibit this exponential growth pattern.

CHAPTER 4

REAL-TIME TRANSIT STANDARDS DEVELOPMENT

4.1 Methodology

The methodology presented here relies on the multiple case study to understand the standards development processes utilized by each data standard. One of the principle aims is to reach an understanding of how "open" each data standard is, or how well each data standard complies to the definition of an open standard. According to Yin, a case study is an empirical endeavor that investigates contemporary phenomena within the context in which they occur. A case study provides a method to observe both the phenomenon and the contextual details—which may be part of what the observer seeks to understand (*45*).

The multiple case study methodology used here relies heavily on document review and past surveys on agency attitudes and capabilities regarding the provision of real-time information to understand characteristics of the standardization processes and their impacts on agency adoption. Interviews were also conducted with members of the SSOs from each of the standards development processes. The final source of information is a collection of articles from a variety of peer-reviewed journals that contain data about various implementations of (1) products deployed by different vendors, (2) standards implemented in different use cases, and (3) opinions/perspectives on standardization and ITS for transit.

4.1.1 Justification for Case Study Methodology

The case study as methodology offers research on systems, processes, and institutions an important tool for understanding. Yin offers the following purposes for choosing this methodology in research:

1. The research seeks to answer a "why" and/or "how" question,
2. The research focuses on contemporary events, and
3. The researchers lack "control over behavioral events" relevant to the research.

(*45*)

The research objectives in this thesis are to understand why and how each of the real-time transit passenger information standards development processes function and to consider how the standards environment could be improved for the better functioning of real-time information provision. This is certainly a contemporary subject of review. While there are some historical considerations, each of these standards is actively evolving over time and each of the respective SSOs consider the future of the standards.

Finally, the researcher draws on insights from members of the SSOs and does not attempt to nor could he control the behavioral events of these bodies. Any analysis of standards development processes necessarily must draw on case study findings, lest the research be focused on developing economic models or theoretical insights. This research, on the contrary, seeks to understand specific real-world processes and institutions and their respective arcs of development.

4.1.2 Components of Case Studies

Interviews

To gain insights into the history and evolution of the standards development process, the researcher conducted interviews with either members of the SSO or persons actively engaged in the standardization process for each data standard. The nature of these interviews were primarily informational, seeking specific facts about the operations and functioning of standards committees rather than opinions or speculations. The interview questions are reproduced in Appendix A: Interview Questions. The major categories for questions asked in the interviews are as follows:

- Interviewee's role in standard development
- History of standard development process
- Meetings, Consensus, and Formal Processes
- IPR, Global Availability
- Transparency, Interface, and Access
- Support for Implementers

Many of the question topics aimed to understand the openness of the respective standard development process according to Krechmer's ten principles of open standards. Internal Review Board approval was obtained for the interview questions and consent from interview participants was obtained. Although these interviews were informational, in order to protect the participants pursuant to human subjects policies, their names are excluded from this thesis. Nonetheless, many parts of the interviews informed the case study analysis.

Document Review

The researcher extensively reviewed documents on the standards and their respective standardization processes. These documents include SSO and/or data standards websites, documentation on current and/or past versions of the data standards, and any publicly available meeting minutes or committee communications. Many of the most important of these documents are referenced in the bibliography and are available on the Internet. However, if at some point in the future, these are no longer available at the URLs provided, please contact the researcher[5] for a copy of the reference material (given that the license governing the use and distribution of the content permits such sharing).

Assessment of Openness

Openness is an important characteristic for standard setting that the researcher has identified in the literature review. As mentioned above, many of the interview questions were directed at understanding how well the standard satisfied Krechmer's ten principles of open standards. A brief description of the most salient features of openness is provided for each case study and a comparative review according to Krechmer's principles is provided at the end of this chapter.

Review of Outcomes

Achieving standardization requires more than simply developing a standard. This is only the first step in a process that, if successful, will lead to the widespread adoption of the standard, the proliferation of network effects to both firms and users, and an improvement in the functioning of the industry market. As such, it is important to review

[5] This researcher may be contacted at lreed3@gatech.edu.

the present outcomes in adoption of each of the standardization processes as indicators of how successful each standardization process has been to date. This is, of course, an ever-changing situation as implementation decisions are made and procurement documents produced in agencies every day. However, there is value in ascertaining the current state of affairs in order to both predict future trends and understand the process that led to the present state.

4.2 Case Studies

4.2.1 GTFS-realtime

<u>Background</u>

History

GTFS-realtime is the real-time complementary standard to GTFS, the General Transit Feed Specification, which contains static schedule information for a transit agency or collection of agencies. The history of GTFS-realtime is tightly coupled with that of GTFS. Portland's Tri-County Metropolitan Transportation District of Oregon, more commonly known as TriMet, worked with Google to originally develop GTFS. Bibiana McHugh is mentioned as having initiating conversations with Google, Yahoo, and Mapquest in a desire to make transit trip planning information as readily accessible as driving directions on popular mapping services (*46*). Chris Harrelson, a Google employee, was already engaged in the integration of transit options to Google Maps. By December 2005, TriMet's schedule information was available on Google Maps as Google Transit (*46*).

A number of agencies followed TriMet's lead. Nearly a year later, Google announced that the company had added five more cities to Google Transit (*47*). A change proposal was later made in 2009, and shortly thereafter adopted, to rename the GTFS standard (it was originally known as the *Google* Transit Feed Specification) to more accurately capture its growing use in many other applications besides Google Maps (*48*). Indeed, the standard has since grown to be adopted by nearly 700 agencies worldwide (*49*).[6] In the U.S., 272 transit agencies had adopted open data policies to provide their GTFS feeds to the public as of March 2013 (*50*). Figure 4 shows this trajectory of growth and when Google decided to tackle the issue of providing real-time transit passenger information.

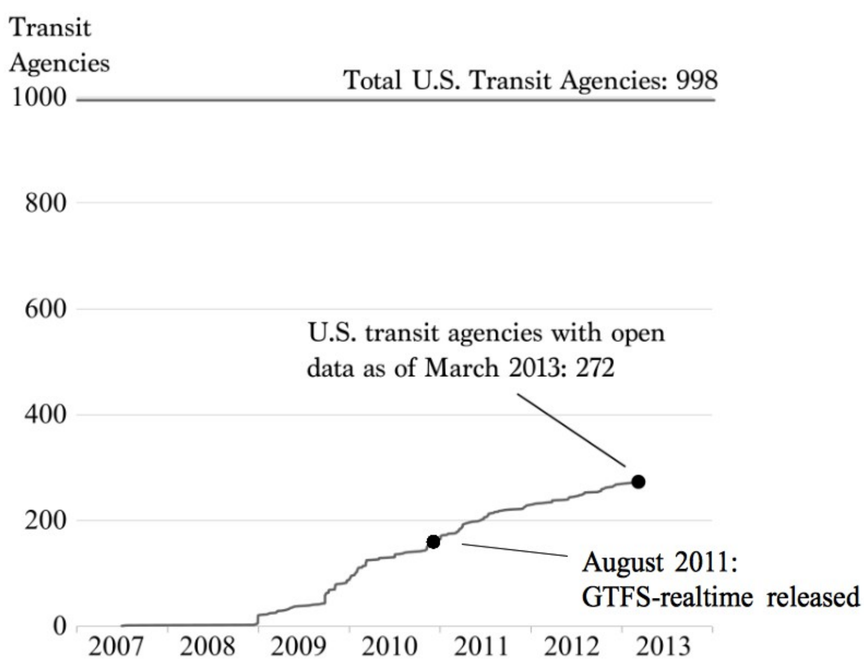

Figure 4 Adoption of GTFS by U.S. transit agencies *(82)*

[6] According to the website http://gtfs-data-exchange.com (accessed on November 7, 2013). This figure includes both official and unofficial feeds as well as some agencies that may have out-of-date feeds. Nevertheless, the scale of this figure is accurate.

Once Google was in the business of providing scheduled transit information, the provision of real-time information followed a natural progression. In the summer of 2011, Google launched Live Transit Updates for Google Transit for Boston, Portland, San Diego, San Francisco, Madrid, and Turin (*51*). This service provides real-time updates on transit vehicle arrival times as well as service modifications/alerts within the Google Maps trip planning function.

The real-time arrival time updates for Live Transit Updates relies on a bulk-delivery data standard known as GTFS-realtime, which Google developed with the help of partner transit agencies listed above as well as a number of individuals involved in the development of applications for transit. The specification, in secret development for about a year before its release, was made open following its release. Thus, GTFS-realtime brought to real-time passenger information what it had done to static information only a few years ago: introduced a robust open standard for moving data from agency and vendor coffers into the hands of third-party developers.

Scope

Google developed GTFS-realtime in order for the company to consume real-time transit feeds in Google Transit. As such, the standard differs in two fundamental ways from TCIP and SIRI, the other two standards considered in this research, which were developed primarily for intra-agency interoperability and communication. First, whereas TCIP and SIRI each allow for payloads of data at the transit vehicle level, GTFS-realtime provides a data payload only for an entire fleet of vehicles, what is often referred to as a "snapshot" of the transit system. While some agencies might have hundreds or even thousands of active vehicles at any given moment, GTFS-realtime is able to efficiently handle this data because it utilizes the lightweight Protocol Buffer data structure up to 10 times smaller and up to 100 times faster than XML serialized data (*52*).

This model differs from utilizing a transactional application programming interface (API) such as the representational state transfer (REST) model that many agencies choose to publish and SIRI has recently adopted as a transport architecture. These transactional models allow for a more active conversation between interfaces. For example, a client-based web application may make transactional requests to an API for the next real-time arrivals for a specific stop (the next five buses to arrive at 5th St and Main St).

The second fundamental way GTFS-realtime differs from the others is that it operates on a strictly one-way communication model. That is, an agency publishes GTFS-realtime for external bulk consumption. TCIP and SIRI offer more capabilities for integrating real-time passenger information with operations. For example, TCIP was developed with the architecture of an entire transit agency in mind. TCIP allows for operational need to connect, for example, a bus' AVL system to other on-board equipment. Similarly, SIRI allows buses to communicate with one another to, for example, ensure that a timed transfer is made smoothly by informing Bus B to wait for the passengers of Bus A if Bus A is running late.

Although these models may differ fundamentally, the primary concern of this research is the delivery of real-time information on stop arrivals/departures, vehicle locations, and service alerts. All three standards perform this function, whether they function at the junction between bus and agency server, agency server and agency web/sign interface, or agency server and third-party interfaces. The open data paradigm has shifted many progressive agencies from keeping data within intra-agency networks to sharing this data outside agency walls. Whether agencies commit to a fully open or semi-open model, the need for an effective data standard for real-time passenger information remains.

Technical Documentation

The documentation for GTFS-realtime (*53*) provides an overview of the standard, description and examples of the feed types, and a complete reference of the specification. The standard has categories for three types of real-time information:

- **Trip updates** – delays, cancellations, changed routes
- **Service alerts** – stop moved, unforeseen events affecting a station, route or the entire network
- **Vehicle positions** – information about the vehicles including location and congestion level. (*53*)

These categories provide for most, if not all, of the crucial information about transit service that passengers might be interested in. Certainly there are more complex pieces of real-time information that are left unaccounted for here, such as information about connections/transfers between routes or detailed data structures about transit facilities. The technical specifications for SIRI, discussed below, capture much more of this type of information and allow for more transactional data exchange models. However, the bulk exchange model for GTFS-realtime requires the specification to be somewhat more minimal than it might otherwise be. This does, however, help the standard to maintain a limited scope and agencies to achieve implementations more easily.

Development

Institutional Involvement

The primary institutions involved in the development of GTFS-realtime are Google and the original six transit agencies who participated in the closed development process. Since then, the specification has been adopted by a few more agencies (although the precise number is difficult to come by). Google staff work actively to coordinate with agencies on bringing them onto Google Maps and, by extension, onto the GTFS specification.

Evolution

The history of institutional involvement for GTFS seems to have been instructive for Google with its foray into real-time data. The company developed GTFS with the benefit of transit industry expertise from a single agency. When the specification was released publicly, there were initially a number of changes proposed and adopted almost immediately. It is likely that Google revised its development strategy and institutional involvement to include additional partners partly because of this experience. Another possible explanation for this change in institutional involvement is that the company wanted to expand its reach for bringing the standard around the globe by releasing Live Updates for Google Transit with an international scope. Regardless of the reason, the development of GTFS-realtime included a broader group of stakeholder institutions, which has likely contributed to a decrease in post-release changes to the standard (see Figure 5).

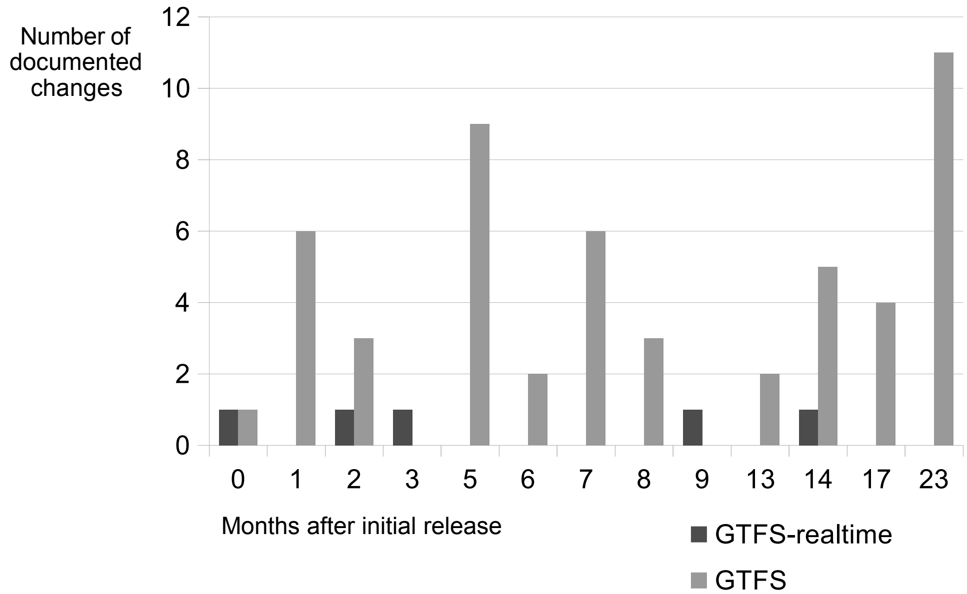

Figure 5 Number of documented changes for GTFS vs. GTFS-realtime (*80*, *81*)

Another crucial piece of the evolution of GTFS-realtime is the growth in "repeaters" that exist for the standard, or small applications that convert a different specification to GTFS-realtime. Repeaters allow agencies that have real-time passenger information in one format to gain the benefits of an open standard like GTFS-realtime. Currently, the known repeaters for GTFS-realtime were developed for use in OneBusAway, the open source suite of tools for delivering passenger information. The repeaters include support for the NextBus, SIRI (Vehicle Monitoring and Situation Exchange), and ACS Orbital OrbCad AVL (*54*). While this bandaid solution to interoperability is not perfect (especially for a proprietary format that could change at a moment's notice) and it may be impractical to consider for every possible proprietary closed format, it does begin to expand the sphere of influence of GTFS-realtime and, importantly, allows for easy integration with the SIRI open standard.

Openness

GTFS-realtime is notable for the openness and transparency that governs it today. Nevertheless, the standard was originally developed in the product development shroud of Google secrecy for which the company is renowned (or notorious, depending on the perspective). Original participants in the development of the specification signed non-disclosure agreements in order to keep the details of the project closed. This is truly the antithesis of openness; however, a participant of the process notes that in the realm of standards development the barriers to initial development and publication are high. This closed process allowed the participants to quickly develop the specification and deploy implementations in the absence of painstaking and meticulous debates with a wide array of stakeholders.

With the release of the standard in 2011, Google removed the barriers to widespread participation. Open communication is maintained on a publicly-accessible mailing list (https://groups.google.com/forum/#!forum/gtfs-realtime). Change proposals, technical issues, and clarifications are all discussed on this forum by an active community of agency staff, Google staff, and transit application developers/enthusiasts. The general policy on changes to the standard is carried over from the policy governing GTFS. That is, in order for a change to the standard to be considered it must see interest both from application developers and transit agencies. The policy is intended to keep the standard from becoming bloated with superfluous data and relevant for all stakeholders. As for intellectual property rights, the specification is published under the permissive Creative Commons Attribution 3.0 License (*55*) and all code samples are available under the Apache 2.0 License (*56*).

Success

As mentioned previously, the static GTFS specification has been adopted by hundreds of transit agencies around the United States and around the world. Because the GTFS-realtime feed works in conjunction with GTFS, it stands to reason that many agencies will invest in making their schedule information work seamlessly with their real-time information. While this sounds simple on paper, in reality many agencies that have AVL and scheduling systems will have different vendors providing each system. Applications that deliver real-time information along with scheduled information (e.g., to provide information on route geometries and stop locations along with real-time arrival times) require the reconciliation of object identifiers in schedule and real-time systems. In other words, trip identifiers or route identifiers in the schedule must match (or be translated to match) those identifiers in AVL systems. Nevertheless, GTFS and GTFS-realtime appear to be in a strong position to serve that role, especially thanks to the support of real-time "repeaters" that translate the NextBus API specification, SIRI, and others into GTFS-realtime (*57*).

4.2.2 TCIP

<u>Background</u>

History

The development of Transit Communication Interface Profiles (TCIP) was initiated by the USDOT's Intelligent Transportation Systems Joint Program Office (ITS JPO) in November 1996. Industry professionals came to the realization that in order for transit technology systems to move forward in a progressive and constructive way, standards needed to be an essential part of the conversation. The standard, funded by the ITS JPO and originally developed by the Institute of Transportation Engineers (ITE), switched ownership to APTA in 2001 primarily because of APTA's stronger expertise in the transit industry (*58*). It was under APTA that the bulk of the standard was developed.

Scope

The primary goals of TCIP are to achieve intra- and inter-agency interoperability and to decrease the negative effects of vendor lock-in. These goals are in direct agreement with the federally-mandated concept of regional ITS architectures. However, another one of its goals according to an APTA presentation from 2010 is to lead to interoperability "between an agency and external Information Service Providers" (*59*). This goal of interoperability with Information Service Providers suggests that the TCIP standard might cater to the recent growth of application developers that have latched on to the open data movement in order to provide information to transit customers. This is indeed an important goal, but may be difficult for TCIP to fulfill simply because of the sheer flexibility and customization that the standard allows[7].

Technical Documentation

The documentation of each version of TCIP (including the current version) is currently hosted on the APTA TCIP website in the form of zipped MS Word documents (*60*). The standard itself is expansive, providing XML-formatted schema for nearly every type of transit technology subsystem and business area imaginable including:

[7] TCIP provides an expansive "menu" of options that can be specified for a given product/interface. For example, there may be 40 different fields (some of which may be required) for a certain message type. However, one vendor in compliance with TCIP may specify ten of these fields for its product, while another vendor specifies ten different fields. Both may be TCIP-compliant, but the interoperability is not necessarily ensured. This is, of course, a concern with any flexible standard, but the breadth of TCIP makes it especially so.

- Scheduling,
- Passenger Information,
- Onboard Systems,
- Common Public Transport,
- Control Center,
- Fare Collection,
- Spatial Referencing, and
- Transit Signal Priority (TSP). (*61*)

Figure 6 shows a diagram of the expansive TCIP Model Architecture. The standard provides building blocks from these schema out of which systems engineers can build interfaces that are compatible with one another.

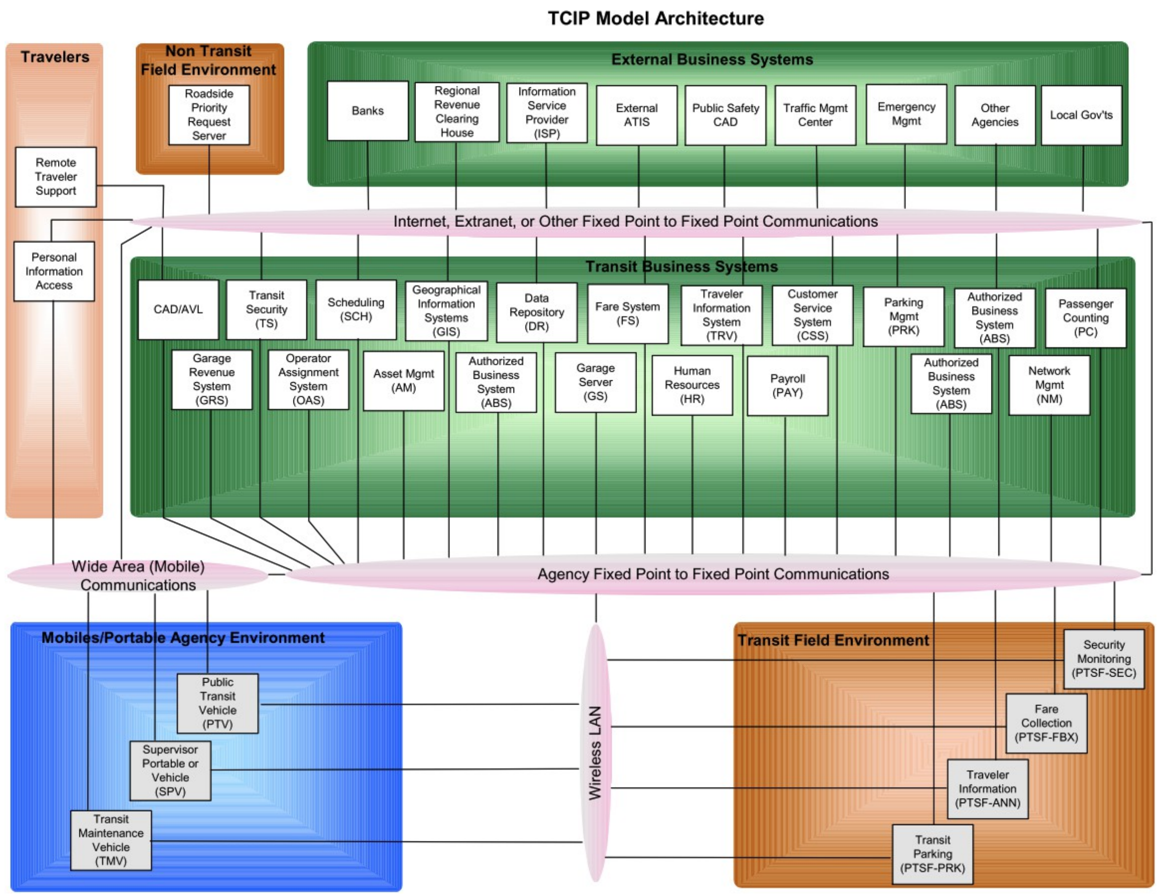

Figure 6 Diagram of TCIP Model Architecture (*59*)

TCIP allows for the construction of system interfaces through a hierarchy of data "elements" that compile into "frames" which compose "messages" that are passed between interfaces in "dialogs" or data exchanges. Figure 7 shows a diagram of this hierarchical organization. This extremely flexible system allows for an immeasurable number of combinations and permutations for systems to communicate with one another. In practice, there may be need for only a few sets of standard messages to send between, for example, a CAD-AVL system and Web-based trip planner. The developers of TCIP have accounted for this by making standard message sets available through TIRCE, or TCIP Implementation Requirements and Capabilities Editor, an application that allows users to build custom message sets and dialogs.

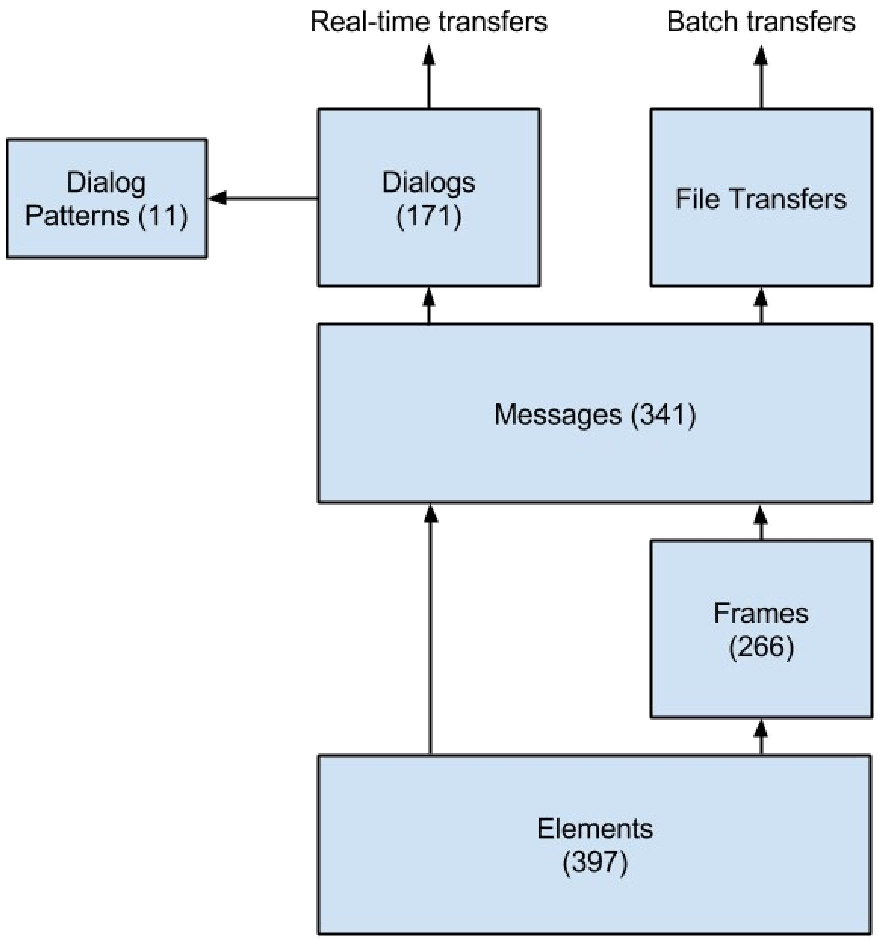

Figure 7 Diagram of conceptual hierarchy for TCIP building blocks (*59*)

Development

Institutional Involvement

While the TCIP standard development process began under ITE, the standard underwent the bulk of its development and refinement while under the direction of APTA. A series of technical working groups (TWGs) composed of a mix of transit agency staff and vendor representatives developed the definitions and schema for TCIP. A TWG existed for each major business area with an additional one for Tools (TWG 4), for a total of 10 TWGs.

An examination of the Passenger Information TWG (TWG 2), for which real-time passenger information messages and elements are defined, shows the institutional makeup of those involved in the standard development process. Figure 8 shows the breakdown of institutional involvement in the Passenger Information TWG. The vendor category is comprised of consultants to APTA, technical staff, and managerial staff. The agency category is comprised of technical and managerial staff from transit agencies. The TWG category is made up of APTA staff.

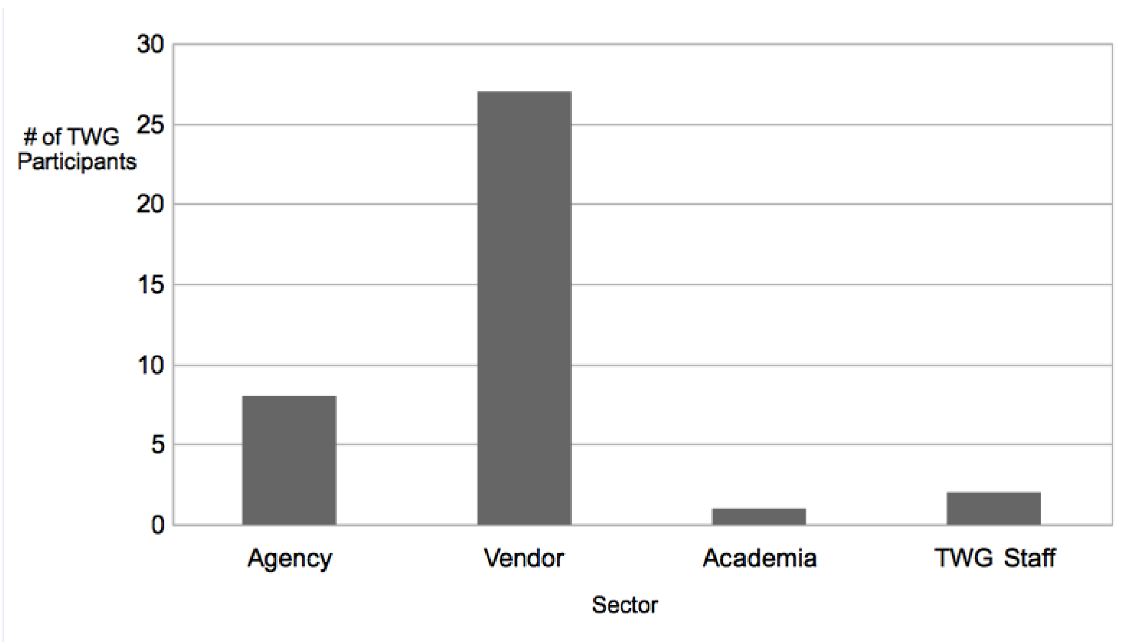

Figure 8 Participants by sector in TCIP Passenger Information Technical Working Group (*83*)

From this chart, it is clear that vendors make up the largest bucket of institutions involved in the standard development process with 27 representatives; agencies make up the second largest group with eight representatives; and TWG staff and academia are the smallest groups with one and two members, respectively. Although, the number of representatives listed on a contact sheet for the TWG is a primitive means to begin to understand the interplay and influence on the standard development process, in the absence of complete and organized minutes of past meetings, it offers a glimpse at how institutions were represented in this process. According to Lehr, there are many scenarios of strategic decision-making that occur within standardization committees. For example, new market entrants and entrepreneurs are more vulnerable to delays and so stable, incumbent firms may attempt to delay standardization outcomes (*62*). Nevertheless, this process necessarily incorporated vendor input because these firms often know many of the technical issues facing standardization firsthand.

Evolution

Most of the development work for TCIP was completed around 2006. The standard moved from active development to a five-year review cycle at that time. A comprehensive analysis on the changes made to TCIP is more difficult than for GTFS-realtime or SIRI (see next section). The TCIP documentation is extremely lengthy, and each version is contained within a series of word documents. This document structure makes a comparison very cumbersome at best, impossible at worst. The versions are, however, labeled according to software numbering conventions and number at a total of fifteen versions (from version 1 to the current version 4.0). The most noteworthy change for this research appears to have come in TCIP version 3.0.5.2, which was issued on March 1, 2012 (*63*).

In version 3.0.5.2 of TCIP, a GTFS timetable importer was included in the standard. While prior to this version TCIP has made reference to a number of other industry-accepted standards, these other standards have all been maintained by accredited SDOs. This is the first acknowledgement that, in some areas, de facto standards and specifications have an important role to play. Indeed, before GTFS there were no de facto standards adopted so widely to be worth including. However, it appears that when hundreds of transit agencies (large and small) began to move towards a specification, APTA took notice and decided to adopt the specification (albeit only as an importer) into its transit standard family.

Openness

The standard development process for TCIP itself was open and transparent, allowing any interested party to be involved in the development or comment on version. APTA's standard development process is modeled after that of the American National Standards Institute (ANSI), a well-established voluntary consensus standards development organization whose membership comprises "more than 125,000 companies and 3.5 million professionals" (*64*). When it comes to transparency, though, there are some issues related to communication of information regarding the TCIP standard.

On the one hand, there is a wealth of information available on the standard's website. Such information includes all previous versions of the standard, archived meeting notes, free support tools for working with the standard, TWG member lists and meeting attendee lists, a database of comments on the standard, and more. While the number of archived documents is impressive, the organization of the material is confusing. Just as the documentation for changes between versions is buried deep within large MS Word documents, so is the information contained within these archives. The content is searchable via a well-indexed search engine, but the organization of the website is poor and nearly all content is in the form of sizable MS Word documents that must be downloaded and parsed through.

Success

Measuring the success of TCIP by the number of implementations for real-time passenger information would suggest that the standard has achieved less than it truly has. There is no good indicator of how many agencies use TCIP to communicate real-time passenger information either within an agency or to a third party. The only well-documented instance of TCIP used for real-time passenger information is the pilot project developed at LYNX (*65*), the Orlando-area system operated by the Central Florida Regional Transportation Authority. This implementation of TCIP, however, will likely be discontinued in the near future according to the interview conducted for TCIP. This is not to say that the standard is not used in other business areas and for related purposes. There have been a number of other pilot projects around the country, including at King County Metro, Maryland MTA, and Chicago Transit Authority. In fact, New York City MTA utilized modified parts of the standard for a recent project[8] to deliver real-time information to customers (*66*). Additionally, a recent TCRP synthesis on electronic passenger information signage in transit reported that six other agencies in the U.S. (not counting NYC MTA) utilized TCIP for real-time passenger information (*67*).

While there are a number of projects that draw on TCIP, the standard is far from achieving its goals of providing intra- or inter-agency interoperability. While these goals might have been achieved in a few cases around the country, TCIP has seen nowhere near the adoption rate of GTFS. Based on the integral relationship between GTFS and GTFS-realtime and other factors discussed in the GTFS case study, this author conjectures that the same dominance will hold true in time for GTFS-realtime. While TCIP may continue to play an important role in ensuring interoperability between subsystems beyond real-

[8] The real-time information system is known as MTA BusTime (http://bustime.mta.info/).

time passenger information and in enabling the pursuit of custom solutions (such as with NYC MTA), it is likely that it will be dwarfed by GTFS-realtime as it continues to grow into new markets.

4.2.3 SIRI

Background

History

Developers of the first version of the Service Interface for Real-time Information (SIRI) began working on the standard between 2004-2005 and the standard officially emerged as a technical specification under CEN in October 2006 (*68*). The standard is a result of the collaborative efforts from "equipment suppliers, transport authorities, transport operators and transport consultants from eight European countries" (*69*) including the Czech Republic, Germany, Denmark, France, Norway, Sweden, and the United Kingdom. SIRI draws heavily from France's TransModel for its conceptual framework, and the UK's Real-time Transport Interest Group (RTIG), Germany's Verband Deutscher Verkehrsunternehmen (VDV), and the EU Trident project provided valuable starting points for the development of the standard.

Scope

The development of SIRI brought together a number of national transit data standardization programs in order to more effectively address standardization at a broader scale. According to SIRI documents, the primary goals for developing the SIRI standard were to give purchasers of real-time systems "a straightforward, watertight way of procuring different components of a public transport information system from different suppliers" and to provide suppliers of such systems "a Europe wide market, ensuring that their systems can be used in every country without needing to implement different interface standards in each region" (*69*).

Thus, the benefits were perceived to be directly attributable back to purchasers (or transit agencies) and suppliers (ITS vendors). An added benefit was the opportunity to update existing standards (whether at the national level or for proprietary systems) to account for emerging technologies (*69*). So, whereas in the U.S., TCIP was the first standardization attempt (outside of proprietary specifications), SIRI was a "next generation" standard for a few nations that had already implemented national standards.

Technical Documentation

Technical documentation for SIRI is available in English on the SIRI website in the form of a white paper (*69*) and, far more extensively, as a handbook (*70*). As with TCIP, SIRI extends far beyond the provision of passenger real-time information (though perhaps not quite so far as TCIP). Among its ten services shown below, or functional data categories, those **in *bold italics*** are those which are typically considered under the umbrella of real-time passenger information:

- *Production Timetable (PT)* – provides information on expected (or scheduled) transit service for a day in the near future
- *Estimated Timetable (ET)* – provides information on real-time deviations for the current day, or only those trips currently in operation
- *Stop Timetable (ST)* and ***Stop Monitoring (SM)*** – gives scheduled information (ST) and real-time deviations (SM) at the stop level

- ***Vehicle Monitoring (VM)*** – sends real-time information on the location of a transit vehicle
- *Connection Timetable (CT)* and *Connection Monitoring (CM)* – gives scheduled information (CT) and real-time deviations (CM) to inform a departing vehicle on the need to wait for an arriving vehicle at a stop or station serving multiple routes
- *General Message (GM)* – exchanges basic text messages between entities
- *Facilities Management (FM)* – provides information on the status of facilities, such as elevators or escalators that are out of order
- *Situation Exchange (SX)* – exchanges structured messages between entities (*68*)

While the Estimated Timetable, Connection Monitoring, and Facilities Monitoring services all provide real-time information that may be of value to the operations and even some customer use cases, they are not necessarily within the scope of this research. Stop Monitoring and Vehicle Monitoring, however, fall well within the definition of providing schedule deviation/adherence and vehicle locations.

Development

Institutional Involvement

SIRI is the result of collaboration between a number of firms and governments throughout the European Union. Working group meetings for the standard are attended by representatives from each member country to CEN, although historically the most participation and interest have come from Germany, France, the UK, and Scandinavian countries. As mentioned above, a few national standards already existed from which SIRI draws a great deal. Because these standards already existed, some interesting accommodations were made in order to satisfy the interests vested in these preexisting standards. For example, in order that previous implementations of the German VDV standard might not be broken, two separate XSDs (XML schema definitions)—a nested and flat version—were maintained for some time. This is a peculiar example of how institutional and political values can outweigh the purely technical in standard development.

Evolution

Like GTFS and GTFS-realtime, a well-organized set of versions and their respective changes is maintained on the SIRI website (*71*, *72*). A list of all changes made since version 1.2 (April 7, 2007) is maintained there, along with—beginning with version 2.0—the country code of who initiated each change (e.g. Germany (DE), the United Kingdom (UK), France (FR), etc.). The SIRI standard began as a CEN technical specification, a "normative document… that would not gather enough as to allow agreement on a European Standard... or for providing specifications in experimental circumstances and/or evolving technologies" (*73*).

The most recent version of SIRI (2.0) was drafted into a proposal in order to become the more robust and rigorous European Standard (EN), a cornerstone of the concept of the Single European Market to facilitate effective trade both within and beyond Europe (*74*). This continued work and development on SIRI signal its continued importance in European markets and even in the US, where the NYC MTA heavily incorporated the standard into its MTA BusTime project mentioned in the TCIP case study above.

Openness

Much like TCIP, SIRI is developed within the confines of a formal, accredited SDO, the European Committee for Standardisation. As such, the standard development process is open and consensus-based, relying on a set of protocols that have been established for the review, adoption, and maintenance of many standards under CEN. Nevertheless, there are components of the SIRI standard that present barriers to open participation and implementation of the standard. For one, meetings for the standards are only open to participants of national committee members. Others may participate as observers, but only on an invitational basis. Further, while the license restricting the use of the standard only requires that copyright holders be acknowledged, formal standard documentation must be purchased via the national member sites (e.g., via VDV's website)[9] and reproduction of any part of supporting standards produced by non-members is prohibited without permission from these copyright holders. These barriers to implementation and participation are minor, but remain impediments to becoming a fully open standard.

Success

The continued and active development on SIRI points to its success as a standard, especially in European markets. However, the standard would not be under consideration had it not seen some interest and adoption in the U.S. market. NYC MTA is one of the agencies that continues to push the evolution and development around SIRI, having adopted it for MTA BusTime and pushing to add JSON (JavaScript Object Notation – a

[9] Purchase of the SIRI specification was confirmed by an interview with a participant in the SIRI standards development process. While there exist sites that host what appears to be the complete SIRI documentation free of charge (http://www.siri.org.uk/), the researcher could not locate the national member sites where documentation or schema were available for purchase.

lightweight, web-ready alternative to XML) formatting and modern web service transport methods to the standard (*75*). There are at least five other U.S. transit agencies reporting usage of SIRI in a recent TCRP Synthesis on the use of electronic passenger information signage in transit (*67*). Compared with the usage of either TCIP or GTFS-realtime this is certainly a strong showing, especially given that this standard was imported from the European Union.

4.3 Comparison of Standards and Standards Development Processes

4.3.1 Assessment of Openness

The framework used here to assess the openness of the real-time standards considered in the case studies draws heavily from Krechmer's ten requirements of open standards. While the categories were interpreted slightly differently than his original descriptions to account for some of the idiosyncrasies of the requirements and to apply them more directly to this case, the open standard requirements remain largely unchanged.

The three case study standards (GTFS-realtime, TCIP, and SIRI) were each given a scoring for the ten requirements. Table 4 shows the scoring of these categories broken out. The scoring methodology was taken directly from Krechmer, with a few modifications for this specific context. Appendix B: Openness Index Scoring describes the breakdown of scoring for each requirement, the range for each category, and a selection of notes that support the scoring decisions presented in Table 4.

The three open standards are considered alongside the NextBus API specification solely to compare with a closed specification from the industry. While TCIP and SIRI perform nearly identically in every category, GTFS-realtime earns higher marks in open meetings, open IPR, open change (a direct representation of its stronger performance in open meeting), and open documents. NextBus, on the other hand, being a closed standard shows a low openness index, although it does earn a few marks in the open world, open documents, and on-going support categories.

Table 4 Openness index scores for real-time transit passenger information standards

Requirements	*Standards*			
	SIRI	TCIP	GTFS-rt	NextBus
Open Meeting	0	0	1	0
Consensus	1	1	1	0
Due Process	1	1	1	0
Open World	1	1	1	1
Open IPR	2	3	4	0
Open Change	0	0	1	0
Open Documents	2	1	3	1
Open Interface	1	1	1	0
Open Access	1	1	1	0
On-going Support	3	3	3	2
TOTAL	12	12	17	4

The results from the above table suggest that GTFS-realtime is a more open standard than either TCIP or SIRI, which are both managed through accredited SDOs. What explains this finding? Krechmer defines open standards as understood from the lens of open source software. This is a very democratic and distributed perspective that values not just consensus-based processes, but also the openness that is ascribed to fully open meetings that are held and recorded for posterity online. It also depends on clear, complete, and available documentation. It is in these areas where GTFS-realtime excels most. Any discussion of the future of the standard is discussed online in an open forum. The IPR licensing is clearly stated and defined on the GTFS-realtime documentation (whereas with the others it is somewhat obscure). The documentation is fully available online and presented in a coherent, concise way.

Certainly, there may come a time when Google decides to move away from providing transit information (though this appears unlikely given its investment in the product worldwide). Yet because GTFS-realtime is so well documented and the content is clearly licensed, GTFS-realtime could easily spin off and continue to develop if the adoption and interest were great enough. It is for these reasons that GTFS-realtime scored higher on the openness index and perhaps why the standard may continue to flourish.

4.3.2 Implementations

Each of the case studies examined the success of implementations for each of three standards. According to data compiled from multiple sources, there appear to be similar levels of adoption for the standards (*67*, *76*). Figure 9 below shows data from the 2013 APTA Survey on real-time information provision, indicating that the closed NextBus specification seems to hold the largest market share[10]. Even comparing with data from TCRP which suggests that TCIP has seven U.S. implementers and that SIRI has six, this observation holds true.

[10] It is also worth noting that, although the survey indicates that 12 APTA member agencies have implemented NextBus, the NextBus website (https://www.nextbus.com/agencies/ accessed on August 2, 2013) reports that approximately 80 U.S. agencies have NextBus real-time systems (this includes APTA member agencies, some of which are duplicated in the list, as well as small university or circulator systems). This suggests remarkable rates of adoption for NextBus and is important to consider, yet this analysis will take into account only those agencies within the scope of this research, i.e. APTA member transit agencies.

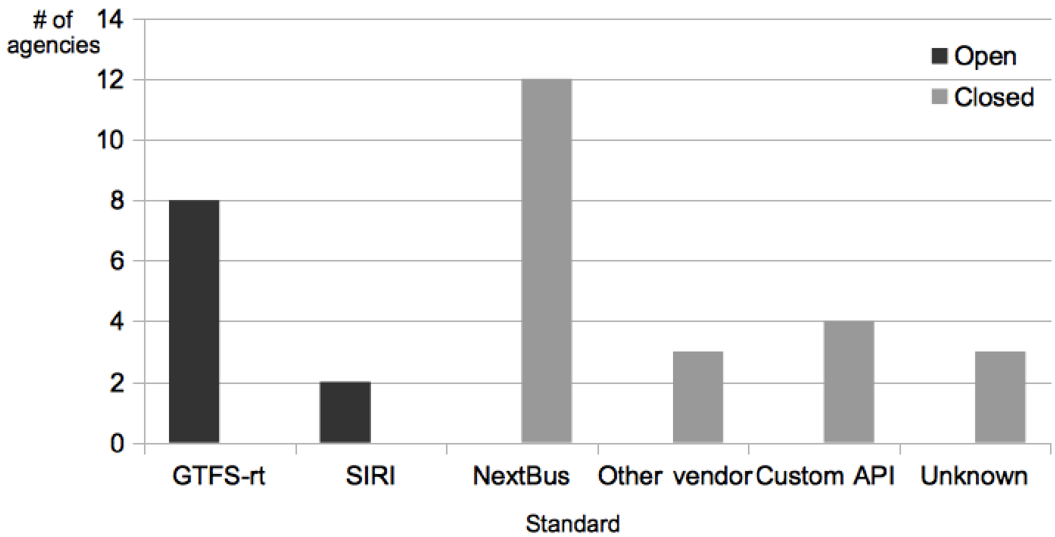

Figure 9 Adoption of real-time data standards (*76*)

An important caveat to the standards' levels of adoption is a look at how these adoption levels have grown over time. This is, of course, a rough an imprecise measure because there are a variety of complex and difficult-to-measure factors that influence standard adoption (network effects, lock-in, etc.). Nonetheless, Figure 9 gives a picture of how quickly these different standards have seen adoption since their inception. The table shows the average number of agencies that have adopted each standard per year. The year of inception is based upon the date that documentation was first made available. For GTFS-realtime and SIRI, there is a strong confidence that the year of inception is accurate. However, for NextBus and SIRI there may be instances where implementations were in place before the year shown.

Table 5 Average adoption rate for (agencies per year) for real-time standards (*67*, *76*)

Standard	*Year of inception*	*Number of agencies*	*Agencies per year*
NextBus	2009	12	3.00
TCIP	2006	7	1.00
SIRI	2004	5	0.56
GTFS-rt	2011	8	4.00

The above table shows that, even though it is relatively new, GTFS-realtime has the second highest number of agencies with implementations and the highest adoption rate (average agencies per year). This finding holds true with reasonable expectations for GTFS-realtime based on its integral relationship to GTFS, which hundreds of agencies have adopted in a period of approximately 7 years (estimated adoption rate of approximately 40 agencies per year). Assuming that Google continues to utilize GTFS-realtime for its products and the standard review process remains open to full public participation, it is likely that this adoption rate will continue to increase.

CHAPTER 5

RECOMMENDATIONS

5.1 Moving Ahead for Innovation in the 21st century

Effective real-time passenger information systems are crucial to satisfying customers' expectations and demands. Transit riders are adopting smartphones and still waiting for the bus. Budget-constrained agencies can deliver this information with relatively little infrastructure by making use of often pre-existing AVL systems and pursuing the open data policies already adopted by President Obama's administration. There are certainly costs associated with this approach, especially if AVL data are contained within a proprietary format. Nevertheless, the open standards that have developed over the past couple of decades allow a path forward to break vendor lock-in and reduce switching costs in the future.

While Moving Ahead for Progress in the 21st Century (MAP-21) addresses ITS in general ways and allocates some funding for ITS (*77*), there are some opportunities to address transportation technology and policy in the next-cycle authorization bill. MAP-21 funding ends with FY 2014, so the next authorization bill will likely be introduced sometime before the current fiscal year ends. The President's Executive Order (EO) on open data for federal agencies offers an opportunity for the USDOT, specifically the FTA, to couple ITS improvements at the local level with open data initiatives. The framework to pursue these initiatives is in place—thanks to progressive agencies such as TriMet and others—should Congress find that such a policy is in the nation's best interest. Open data, besides being a force for government transparency and cost effectiveness, provides sparks for innovation in both the public and private sectors.

One major criticism in this paper of TCIP is that documentation on the standards development process and the standard itself is difficult to consume. As mentioned above, understanding the changes between versions of the standard is difficult because there is no list of versions and their respective changes over time. If this is difficult for the researcher, it is almost certainly difficult for any organization interested in implementing the standard. Therefore, another recommendation that follows the aim of transparency from the open data EO is to substantially reorganize this content to improve not only how the comprehensibility of the information therein, but also to simply improve the transparency of the project generally.

5.2 Predictions for Continued Trends

Based on the historical success of GTFS and the indirect network effects that bundle the static specification with its real-time component, there will likely be widespread adoption of GTFS-realtime in the near future. The 2013 survey on real-time arrival information by APTA (*76*) and TCRP Synthesis 104 on electronic signage by Schweiger (*67*) mentioned above both capture a great deal of valuable information about the current market for real-time information.

One point drawn from the market analysis provided by the APTA survey is that there is immense demand by agencies to share real-time passenger information with their customers. Currently only 37% of agencies are providing real-time information via an API or web or mobile application. For agencies without AVL systems, the vast majority of them (92%) are interested in installing AVL on their vehicles. Even of those agencies that *have* AVL systems already, 47% currently do not provide customer-facing real-time arrival times.

The benefits of public-facing (especially mobile) information systems have been well established (see Chapter 1), so it is likely that the agencies with AVL but without public-facing systems will soon move forward with a public-facing solution. In fact, Figure 10 shows the reasons agencies are not providing arrival times to the public. While 8% of these agencies have projects in progress and a handful of others have organizational or technical restrictions, over 20% simply are constrained by technical ability or funding constraints. As open standards diffuse into the market, economic theory dictates that the cost of implementation will decrease, making feasible solutions a realistic option for more and more agencies.

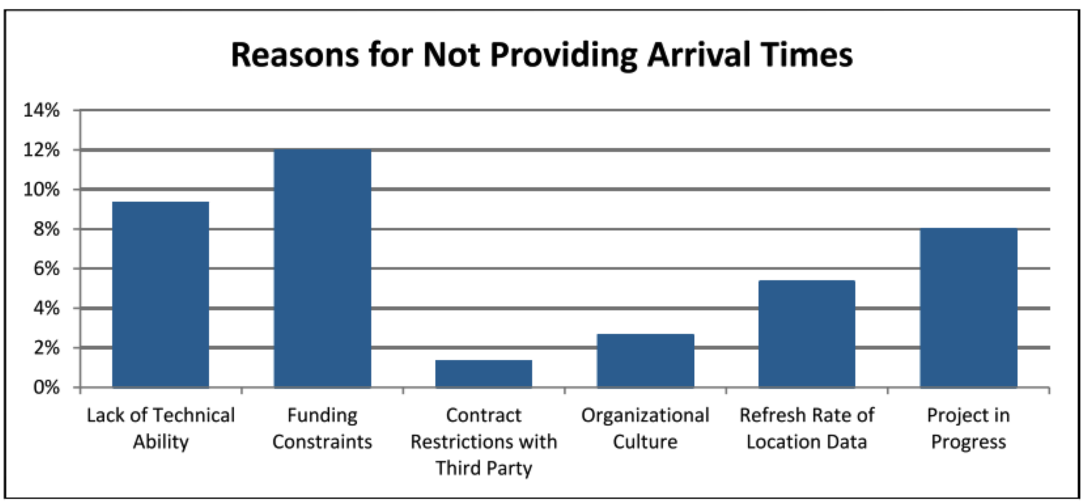

Figure 10 Reasons given by transit agencies for not providing public arrival times (*76*)

By cross-referencing data sources that capture the usage of real-time transit passenger information standards, it appears that SIRI, GTFS-realtime, and TCIP all have a similar number of implementations in the U.S. However, the adoption rate for GTFS-realtime far outpaces that of either SIRI or TCIP (and even beyond that of NextBus, a popular proprietary solution). Anecdotal evidence from open source repository hosting applications such as GitHub (https://github.com) suggest that software development is most active around GTFS-realtime. While this should not serve as concrete evidence of adoption or even transit agency interest, it does bring up the question of how open movements (open standards, open data, and open source) overlap and reinforce one another and how this might apply to the case of real-time transit passenger information.

5.3 Federal Policy Recommendations

To date, there has been little visible response from the federal government to the development of alternative de facto standards for passenger information such as GTFS and GTFS-realtime. True, GTFS was incorporated into TCIP in version 3.0.5.2 of the standard that was issued on March 1, 2012. However, it is unclear how effective the inclusion of this GTFS timetable importer has been for the proliferation of TCIP and, consequently, how effective such action would be for including translators or importers between GTFS-realtime and TCIP or SIRI and TCIP. It seems that the federal government could take one of a few alternative paths of engagement to respond to the likely proliferation of GTFS-realtime or the possible proliferation of SIRI in the United States. The paths listed here are as follows:

1. **Achieve Interoperability** – work to develop translators or importers for de facto standards to keep TCIP relevant (as with static GTFS). In 2012, APTA released a new version of TCIP that included the functionality to import static GTFS "timetables" into TCIP-formatted messages. This could be an approach for keeping TCIP interoperable with real-time passenger information provided by agencies with GTFS-realtime, SIRI, or any other open standard.

This path *is not* recommended by this researcher because the cost of the approach is shouldered by the public sector rather than developers or vendors that otherwise might be incentivized to shoulder the development work themselves.

2. **Provide Guidance to or Incent Vendors/Agencies** – shift focus to providing guidance on the development of open systems and use of open standards where real-time passenger information is concerned. Incenting vendors or agencies to provide open standards is listed as one of the FTA strategies to study in a 2011 FTA report prepared by the Volpe Center (*11*). The status of this program is currently unknown. However, the approach listed in this document promoted incentivizing only the adoption of TCIP. A more flexible approach would be to incentivize the adoption of any one of a set of open standards (perhaps any one of the three standards studied in this research). Such an action would (a) encourage a flexibility of approaches that would all be open, (b) allow market forces to shape an efficient outcome, and (c) possibly spur the market of vendors or civic hackers to further develop translator/repeater to convert from one standard to the next.

   This path *is* recommended because it draws a balance between cost effectiveness and ensuring the promulgation and (possibly) eventual interoperability of all open standards concerned. In this approach, there may be costs involved with incentives provided (whether they be financial or not), but these costs are likely to be less than Approach 1 and have the added benefit of engaging all stakeholders actively. Additionally, this path provides opportunities for the TCIP standard to be adopted for other functional areas within transit agencies. If GTFS-realtime in fact becomes a de facto standard for real-time passenger information (just as GTFS has already become), agencies may find greater benefit in TCIP if the standard is compatible with GTFS-realtime.

3. **Follow Existing Path (Do Nothing)** – do not respond to the high adoption of real-time passenger information standards; let the market manage the adoption of standards and rely on regional ITS architectures to guide this process. **This path *is not* recommended** because it ignores the clear response of agencies to adopt open standards, whether TCIP or not. This policy response does not work to effect change or assist agencies or vendors that are interested in supporting open standards and, in turn, promoting the goals of regional ITS architectures to intra- and inter-agency interoperability as well as interoperability with emerging technologies and systems.

CHAPTER 6

CONCLUSION

This research has addressed the history and background of federal ITS policy and the role of real-time transit passenger information. A comprehensive literature review of standard setting theory has helped to frame the multiple case study approach to understanding and reviewing the standard development processes for and institutional influences on GTFS-realtime, TCIP, and SIRI—the major open standards used in the U.S. for the delivery of real-time transit passenger information. Among the impacts analyzed here are the effect that the standard development processes have had on the adoption and diffusion of the standards, or the "success" of each standard. Federal policy recommendations on the role of government in this area of growing importance are provided here as well.

6.1 Key Findings

A crucial finding of this research is that standards that open themselves to participatory and democratic processes (characterized by clear documentation, open communication—e.g. via mailing list—and rough consensus) may begin to play a larger role in technology and society. This has been demonstrated by Krechmer and others (*24*, *25*) with the influential role that IETF has played in building standards for the Internet—a process which is not without criticism or issues of its own (*78*)—one of the most important technology systems for today's economy and society.

These case studies also suggest that early, on-the-ground implementations of standards are critical to achieving adoption. Much like IETF, GTFS-realtime began as an invitation-only group in order to get rough installations of the standard implemented and working before opening the standard to the general public. This model is unable to account for the complex and comprehensive standards that may result from committee, but perhaps the committee approach is not always the most effective way to see standardization occur in an industry—unless broad consensus is met on implementation of the standard as with HDTV in the U.S. (see Public Policy and Standards Development).

As a strategy to achieve interoperability in this important area of transit ITS, the researcher recommends an incentive strategy for the federal government to promulgate open standards for real-time transit passenger information. By incenting vendors and agencies to adopt *any* open standard (not just TCIP), the FTA would (a) encourage a flexibility of approaches that would all be open, (b) allow market forces to shape an efficient outcome, and (c) possibly spur the market of vendors or civic hackers to further develop translator/repeater to convert from one standard to the next. Such an approach would be cost-effective, engage the broadening base of stakeholders, and embrace the language supporting open and machine-readable government information in President Obama's Executive Order 13642.

6.2 Future Work

Future work should include a comprehensive and systematic survey of transit operators, vendors, and the emerging group of contributors to transit web and mobile information systems. In addition to confirming the exact interfaces and standards implemented (in past surveys, responses sometimes indicate contradictory or confusing results), the survey should quantify perceptions and attitudes about open and proprietary standards. Commendably, APTA has begun to do this with their 2013 survey (see Figure

11), yet a cross-sectional look at not just agencies, but also vendors and other contributors, will help to clarify a complete vision of the state of standards development and adoption for real-time transit passenger information.

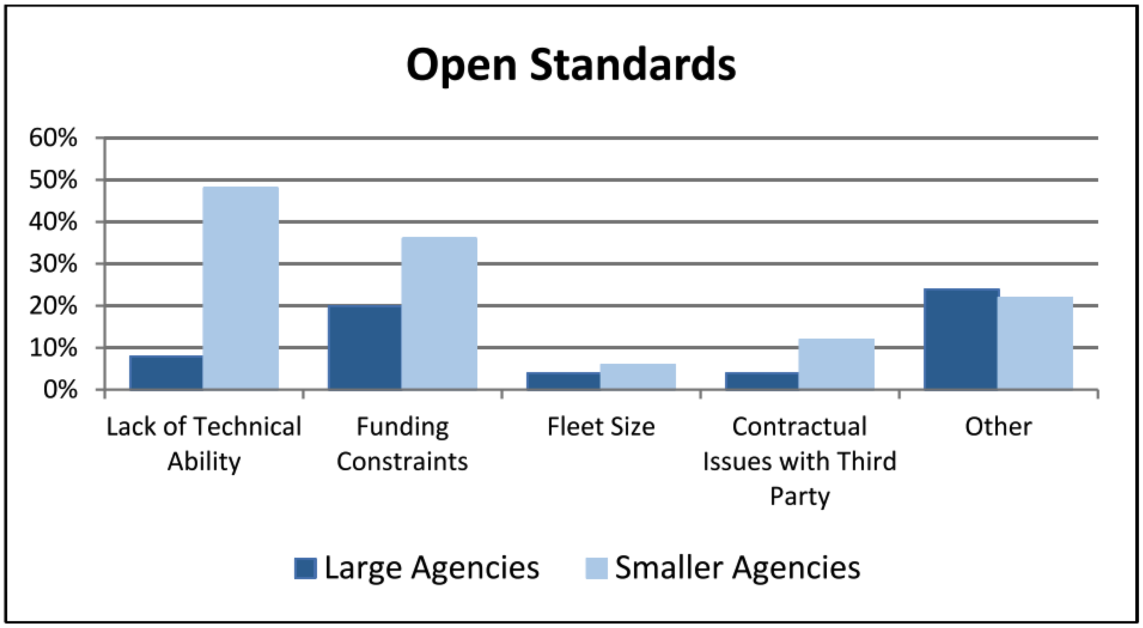

Figure 11 Issues agencies have with adoption of open standards for real-time data (*76*)

This proposed survey could tap the members of mailing lists maintained on Google Groups dedicated to the discussion of these specific standards (such groups currently exist for GTFS-realtime and SIRI) and the development of transit applications generally. It would be instructive, too, to revisit the vendor perspectives on open standards explored by Hickman in 1998 (*38*). While this research considered only APTA member transit agencies, expanding the scope to all transit operators in the region (including small circulators and university systems) would help to clarify the overall picture of perspectives on open standards.

Another future research area that may already be underway at FTA is to understand what kind of incentive structure would best spur agencies and vendors to adopt open standards. Currently the research scope for agency and vendor incentives at FTA only allows for TCIP; however, it is crucial that other open standards for real-time transit passenger information be recognized as an integral pieces to a larger puzzle. The comprehensive survey work described above would help to clarify the type of incentives needed to move the industry toward open standards.

While such research would be valuable to understanding motives and market forces currently in play, the next few years of standardization may obviate the need for such research. As open standards spread in the United States and the demand for real-time transit passenger information grows stronger, the industry may reach the tipping point of de facto standardization, enabling an efficient and effective marketplace for both purchasers and suppliers of real-time systems. The adoption of a standard by an industry and even a single agency is a complex phenomenon, full of many difficult to measure externalities. However, the open standards marketplace and the standards themselves can be made more efficient and effective through greater transparency and the further democratization of the standards development process.

APPENDIX A

INTERVIEW QUESTIONS

Interview Questions

Interviewee's role in standard development

- Were you involved in the initial development of the standard?
  - If so, what was your role in the past?
  - What is your role now?
- What are the number of hours you commit to the standard per month or week?
  - How would you define the nature of this work?
    - Support
    - Development
    - Stakeholder Coordination
    - Other
  - How has this commitment level changed over time?
- Do you work closely with others on the standard?

History of standard development process

- When did the standard development process begin?
  - Did the standards development process begin with a different organization?
  - If so, how did the transition between organizations occur?
- Have changes been made to the standard itself over time?
  - If so, how frequent have these changes occurred?
  - Could these changes be categorized as major (structural or purpose) or minor (technical details)? Do you have any examples?
  - What are some changes currently under consideration for the standard?
- How have the different groups of stakeholders for the standard changed over time?
  - Who are the existing stakeholders?
  - Would you characterize each of these stakeholder groups as active, moderately active, or inactive?
- How do you anticipate the standards development process to change in the future?
  - Do you expect changes to the goals or purpose of the standard?
  - Do you expect changes to the organization charged with developing the standard or governance of the standard?
  - Do you expect major substantive changes to the standard itself?

Meetings, Consensus, and Formal Processes

- Are meetings held to discuss the standard development?
    - What is the forum for these meetings (in other words, are they held electronically, over email, in person)?
    - What is the frequency of these meetings?
    - Are these meetings open to the public?
    - How and to whom are these meetings publicized?
- Is consensus a requirement for decision making?
    - How is consensus defined in this context (somewhere between 51% and 99%)?
    - If consensus is not reached what happens to the issue at hand?
- What are the formal procedures that must be followed when considering change proposals, comments, or change adoptions?
    - May anyone make their views known?
    - What must occur for a change to be adopted formally into the standard?
        - Are there balloting procedures?
        - Who can participate in the balloting?

IPR, Global Availability

- Under what license is the standard provided?
    - Are there restrictions on the use of the standard?
    - Do these restrictions infringe upon reasonable and non-discriminatory (RAND) terms?
- Could the standard be implemented anywhere in the world?
    - Are there technical restrictions on its use in another country (such as language or character encodings)?
    - Is the standard dependent on other standards that are only available on a local, regional, or national basis?

Transparency, Interface, and Access

- Are discussions pertinent to standard made in a public forum, where anyone may participate?
- Are work-in-progress documents (technical proposals, meeting minutes/reports, or proposed changes) made openly available and published publicly?
    - If not, to whom are these documents available?
- Is documentation on the final standard available publicly?
- Is there a method by which interested parties can be alerted to news related to the standard?
- Are different versions of the standard developed to be forward and backward compatible?
    - What is required of implementers in order to make an implementation of the standard function with a different version?
- Are implementers of the standard able to verify conformance with the standard?

    - Are users able to verify conformance?
    - What tools are available for validating an implementation?
- Are there multiple implementations of the standard available that users can access?

Support for Implementers

- Is support for the standard on-going and available for any user or implementer?
    - If not, what are the restrictions on support for the standard?
- Are the phases in the lifetime of the standard for which support is not provided?
    - The five phases of a standard's lifetime can be defined as: (1) creation, (2) fixes, (3) maintenance, (4) availability, and (5) rescission.

APPENDIX B

OPENNESS INDEX SCORING

Requirements	*Range*	SIRI	
		Score	Notes
Open Meeting	(0-1)	0	Meetings are primarily only open to member countries, though there may be occasional exceptions to invite contributors on an ad hoc basis.
Consensus	(0-1)	1	Proposals are approved on a consensus basis.
Due Process	(0-1)	1	Due process is followed per CEN policies.
Open World	(0-1)	1	There are implementations in a number of European countries as well as in the United States.
Open IPR	(0-4)	2	According to the SIRI website, the schema is copyright of the member companies and organizations. The schema may be used as long as these bodies are acknowledged. However, the schema may not be reproduced without permission of the identified copyright holders.
Open Change	(0-1)	0	The first five requirements are not met.
Open Documents	(0-3)	2	Documentation for the current standard (and past versions) is freely available. The documentation is well organized and easy to consume. However, according to the interview, the official documentation must be purchased from national member sites. This could not be confirmed after through research and so may need future investigation.
Open Interface	(0-1)	1	The specification aims to meet forward and backward compatibility principles.
Open Access	(0-1)	1	The SIRI website makes available a number of examples to verify compliance against as well as a number of implementations around the world.
On-going Support	(0-3)	3	According to interviews, SIRI has an active community that contributes to ongoing support of the standard. The strong interests of CEN member countries in the standard suggests that it will see lifetime support.
TOTAL		12	

Requirements	*Range*	TCIP	
		Score	Notes
Open Meeting	(0-1)	0	While meeting participation is available to all parties and there are some meeting minutes available online, implementers have no way to easily consume all of these documents nor is there a clear path to becoming involved in meetings on the standard.
Consensus	(0-1)	1	Proposals are approved on a consensus basis, which is documented on the TCIP website.
Due Process	(0-1)	1	Due process policies are documented on the TCIP website.
Open World	(0-1)	1	There are implementations in the US and Canada.
Open IPR	(0-4)	3	According to interviews, use and redistribution of the standard is permitted. However, the licensing is not clearly indicated on the website for the standard or in any documentation.
Open Change	(0-1)	0	The first five requirements are not met.
Open Documents	(0-3)	1	Documentation for the current standard (and past versions) is freely available. However, the documents are poorly organized and difficult to consume. The availability of meeting minutes is patchy. Understanding the changes made to each subsequent version is cumbersome.
Open Interface	(0-1)	1	The standard aims to meet forward and backward compatibility principles.
Open Access	(0-1)	1	Accessing and verifying the validity of other implementations is made easy with free tools to process and develop message sets.
On-going Support	(0-3)	3	APTA engages in a regular maintenance plan to review and revise TCIP on a periodic basis.
TOTAL		12	

Requirements	Range	GTFS-rt	
		Score	Notes
Open Meeting	(0-1)	1	Meetings are open to any and all contributors and are accessible via a mailing list on a Google Group.
Consensus	(0-1)	1	Proposals are approved on a consensus basis.
Due Process	(0-1)	1	Change proposals and comments are vetted in a transparent forum on the mailing list. In order for proposals to move forward, they must have support by both a developer and implementer.
Open World	(0-1)	1	The specification was released with implementations in the US, Canada, Spain, and Italy.
Open IPR	(0-4)	4	The license for the specification is clearly published. Use of the standard is permissive and parameters on its use and redistribution are clearly outlined.
Open Change	(0-1)	1	The first five requirements are met.
Open Documents	(0-3)	3	The documentation for the specification is clear and concise. There is clear documentation on how to use the specification. "Meeting minutes" and discussions are fully preserved on the mailing list
Open Interface	(0-1)	1	The specification aims to meet forward and backward compatibility principles. Extensions made to the standard will not break the existing standard.
Open Access	(0-1)	1	Accessing and verifying the validity of other implementations is made easy with open source tools to process implementations.
On-going Support	(0-3)	3	Because the standard is available with an express and permissive license and because the standard is not housed within a formal SDO, the maintenance of the specification could proceed even if Google decided to abandon the standard.
TOTAL		17	

Requirements	*Range*	NextBus	
		Score	Notes
Open Meeting	(0-1)	0	There is no open meeting to discuss the NextBus specification.
Consensus	(0-1)	0	While NextBus clients may be able to influence the specification to some degree, the ultimate decision belongs to NextBus.
Due Process	(0-1)	0	There is no formal process for filing comments on the specification.
Open World	(0-1)	1	The specification has implementations in the US and Canada.
Open IPR	(0-4)	0	The specification is distributed with the NextBus copyright and may not be used except by NextBus Inc.
Open Change	(0-1)	0	The first five requirements are not met.
Open Documents	(0-3)	1	Documentation for the current specification is freely available. However, future changes and documents on committee meetings or change proposals are not available.
Open Interface	(0-1)	0	The specification does not meet requirements for open interface including backward and forward compatibility principally because documentation on changes and schema downloads are not fully available.
Open Access	(0-1)	0	Outside of NextBus Inc.'s website there is no way to access implementations.
On-going Support	(0-3)	2	Support for the standard appears to be available during most phases of the specification's lifetime.
TOTAL		4	

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